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Massachusetts Military Reservation

INSTALLATION RESTORATION PROGRAM FS-12 SOURCE AREA REMOVAL ACTION SUMMARY REPORT MASSACHUSETTS MILITARY RESERVATION CAPE COD, MASSACHUSETTS

FINAL

March 2000

Prepared for:

AFCEE/MMR

Installation Restoration Program

322 East Inner Road

Otis ANGB, MA 02542

DSA: 557-4670 COMM: 508-968-4670

Submitted by

Advanced Infrastructure Management Technologies

(AIMTECH, Formerly Known as HAZWRAP)

Oak Ridge, Tennessee 37831-7606

managed by

LOCKHEED MARTIN ENERGY SYSTEMS

for the

U.S. DEPARTMENT OF ENERGY

under contract DE-AC05-84OR21400

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- A Correspondence between Jim Snyder, AFCEE, and Paul Marchessault, EPA Region I, Re: FS-12 Source Area Closure, dated November 9, 1998 and March 1, 1999.
- B Analytical Results for Source Area Groundwater Samples Collected on March 17, 1998.
- C Analytical Results for Soil Samples Collected from Borings SB-1 through SB-10.
- D Letter (with attachments) from M.C. Wheeler and B.T. Sullivan, HAZWRAP), to Dan Santos, Installation Restoration Program, Subject: FS-12 Free Product Investigation, dated March 11, 1993.
- E Letter (with attachments) from M.C. Wheeler and B.T. Sullivan, HAZWRAP), to Dan Santos, Installation Restoration Program, Subject: FS-12 Free Product Recovery Modeling, dated May 18, 1993.
- F Memorandum from Joe Hawk, Commodore Advanced Sciences, Inc. to Carl Wheeler, HAZWRAP, Subtext: Flow Rate Measurements Throughout Soil Vapor Extraction Well Field and Off-Gas Treatment System, dated July 8, 1996.
- G Flow Measurement Test Report, Prepared by Atlantic® Environmental Technologies, Inc., dated September 19, 1996.
- H Re-evaluation of Source Area Vacuum Pressure Distributions as a Result of Actual SVE System Flow Rates Being Less than Design Flow Rates.
- I Boring Logs of Soil Borings SB-1 through SB-10 Used to Verify Site Closure. (Reference Section 8, Figure 8.1, of this Report for Boring Locations.)
- J Unitech Memo to AFCEE, Subject: Estimation of Free Product at Source Area of FS-12, dated September 8, 1998.
- K Letter (with attachments) from AFCEE to EPA/MA DEP, Subject: Shutdown of Catalytic Oxidation Unit at FS-12 Source Remediation System.

ACRONYMS

acfm	actual cubic feet per minute
AFCEE	Air Force Center for Environmental Excellence
AIMTECH	Advanced Infrastructure Management Technologies (formerly known as HAZWRAP)
ANGB	Air National Guard Base
AOC	Area of Concern
ARAR	Applicable or Relevant and Appropriate Requirement
AS	air sparging
ASI	Advanced Sciences, Inc.
AS/SVE	air sparging/soil vapor extraction
BTEX	benzene, toluene, ethylbenzene, and xylenes
BWP	Bureau of Waste Prevention
CAS	Commodore Advanced Sciences, Inc.
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
CO ₂	Carbon Dioxide
DGC, Inc.	Dave Gardner, Contractor, Inc.
EDB	ethylene dibromide (1,2-dibromoethane)
FS	Feasibility Study
FS-12	Fuel Spill-12
HAZWRAP	Hazardous Waste Remedial Actions Program
IAG	Interagency Agreement
IRP	Installation Restoration Program
JP-4	jet propulsion fuel (JP-4)
MA DEP	Massachusetts Department of Environmental Protection
MCP	Massachusetts Contingency Plan
MMR	Massachusetts Military Reservation
NCP	National Contingency Plan
NGB	National Guard Bureau
NAPL	non-aqueous phase liquid
NPL	National Priorities List
O ₂	Oxygen
PID	photoionization detector

ACRONYMS (Cont'd)

PME	performance monitoring evaluation
POC	Point of Contact
ppb	parts per billion
ppm	parts per million
psia	pounds per square inch absolute
PVC	polyvinyl chloride
RI	Remedial Investigation
scfm	standard cubic feet per minute
SVE	soil vapor extraction
TPH	Total Petroleum Hydrocarbons
USEPA	U.S. Environmental Protection Agency
USPFO	U.S. Procurement and Finance Office
UTES	Unit Training Equipment Storage
VOC	volatile organic compound
VPH/EPH	volatile and extractable petroleum hydrocarbons

EXECUTIVE SUMMARY

This Removal Action Summary Report is being issued by the Air Force Center for Environmental Excellence (AFCEE) under the Installation Restoration Program (IRP) at the Massachusetts Military Reservation (MMR). AFCEE implemented a removal action to address contamination associated with an abandoned fuel pipeline leak defined as the Area of Concern (AOC) Fuel Spill-12 (FS-12) source area at the MMR on Cape Cod, Massachusetts.

The remedial construction, quality assurance, and documentation procedures of the General Contractor [Dave Gardner, Contractor, Inc. (DGC, Inc.) of Monument Beach, Massachusetts], as reviewed by Commodore Advanced Sciences, Inc. (CAS) [formerly known as Advanced Sciences, Inc. (ASI)], indicate that the removal action requirements have been completed to the extent practicable as specified in the Action Memorandum (*ASI 1996*).

AOC FS-12 is the location of a leak in a now abandoned fuel pipeline along the MMR border in the Town of Sandwich. The pipeline carried both jet fuel and aviation gasoline during its use from 1965 to 1973. The leak was reported to have occurred in 1972. Monitoring wells were installed during January and February of 1993 to estimate the extent of floating/free product (*NGB 1993*). The FS-12 source area was subsequently identified as approximately 11 acres of contaminated vadose zone soil, groundwater, and floating product (*ASI 1994*).

Pilot studies were conducted at the FS-12 source area during August and September of 1993 to provide information concerning the effectiveness and implementability of proposed air sparging/soil vapor extraction (AS/SVE) and free product recovery technologies. CAS prepared and issued final plans and specifications for remediation of the FS-12 source area, via a combined AS/SVE system (*ASI 1994*). The National Guard Bureau (NGB) subsequently awarded the contract for installation and operation of the FS-12 remediation system to DGC, Inc.

In early 1996, AFCEE assumed management of the MMR IRP program. A Final Action Memorandum (*ASI 1996*) was issued in November 1996 to document a decision by AFCEE to conduct a time critical removal action at AOC FS-12. The Final Action Memorandum (*ASI 1996*) provides a written record of the decision process for removal of the jet fuel identified beneath the fuel pipeline at AOC FS-12, via a combined AS/SVE system, and explains the rationale for this removal action. Source removal at FS-12 was conducted as part of a time critical removal action in accordance with the National Oil and Hazardous Substance Contingency Plan (*NGB 1993*).

The purpose of this FS-12 Source Area Removal Action Summary Report is to document the removal activities at the FS-12 source area and verify performance standards were met where applicable. The AS/SVE system commenced operation on October 23, 1995 and was shut down on February 25, 1998.

Closure sampling was conducted, in accordance with requirements specified in Appendix B of the Final Action Memorandum (*ASI 1996*), and as agreed upon by AFCEE, U.S. Environmental Protection Agency (USEPA), and Massachusetts Department of Environmental Protection (MA DEP), and involved the collection of 40 subsurface soil samples. Twenty samples each were collected within the vadose zone and within the zone of saturation. The soil samples were analyzed for Volatile and Extractable Petroleum Hydrocarbons (VPH/EPH), and ethylene dibromide (EDB), also known as 1,2-dibromoethane. Analytical

results from all samples within the vadose zone were below the MA DEP Category Method 1 S-3/GW-1 and Method 1 S-3/GW-3 soil cleanup standards (310 CMR 40.0975(6)(b)). Only 2 of the 20 soil samples collected below the water table contained contaminants (VPH and EPH) at concentrations above MA DEP soil cleanup standards.

Soil boring locations were chosen to evaluate the effectiveness of the remediation system within the estimated source area and along the perimeter of the source area. Soil borings, when possible, were located in areas where soil analytical data existed and/or free product was detected prior to operation of the remediation system to allow for a more quantitative determination of the effectiveness of the remediation system.

Groundwater sampling conducted on March 17, 1998 indicated the presence of EDB, benzene, and toluene at concentrations exceeding MA DEP Category Method 1 GW-1 and Method 1 GW-3 groundwater cleanup standards. In a March 1, 1999 letter from USEPA to AFCEE regarding FS-12 source area closure (Appendix A), the USEPA and MA DEP agreed that elevated levels in the zone of saturation would not be effectively addressed by continued operation of the AS/SVE system. As a condition to shutdown of remedial action at the FS-12 source area, AFCEE agreed to monitor ten (10) selected groundwater-monitoring wells on a semi-annual basis as part of the existing FS-12 performance monitoring evaluation (PME) program (Appendix A). During initial sampling of these 10 wells, three of the wells were unable to be sampled. Therefore, a decision was made, with concurrence from the regulators, to add an additional well and to eliminate these three wells from the FS-12 PME program. Thus, a total of eight (8) wells were added to the FS-12 PME program, and the results are included in the applicable quarterly reports submitted to USEPA and MA DEP. Based on results of groundwater (Appendix B) and soil (Appendix C) closure sampling, the scope of work as specified in the Action Memorandum (ASI 1996) has been completed to the extent practicable with the condition that post-closure groundwater sampling be conducted as part of the FS-12 PME.

1. INTRODUCTION

This Removal Action Summary Report is being issued by the Air Force Center for Environmental Excellence (AFCEE) under the Installation Restoration Program (IRP) at the Massachusetts Military Reservation (MMR). AFCEE implemented a removal action to address contamination associated with an abandoned fuel pipeline leak defined as the Area of Concern (AOC) Fuel Spill-12 (FS-12) source area at the MMR on Cape Cod, Massachusetts.

On June 28, 1993, the National Guard Bureau (NGB) provided formal notification of its intent to conduct a time critical removal action in accordance with the National Contingency Plan (NCP) to remove jet fuel that had been identified beneath a former fuel pipeline at the AOC FS-12 source area at the MMR on Cape Cod, Massachusetts (*NGB 1993*). In February 1995, construction began on a combined air sparging/soil vapor extraction (AS/SVE) system. The AS/SVE system was operational from October 1995 through February 1998.

System closure criteria, as defined in the Final Action Memorandum (*ASI 1996*), included:

1. The VOC recovery rate average is less than 0.5 lb. per SVE well per day over three consecutive sampling periods.
2. Groundwater analytical results indicate BTEX and EDB concentrations are less than MA DEP Method 1 GW-1 and Method 1 GW-3 Cleanup Standards.
3. Soil analytical results indicate BTEX and EDB concentrations are less than MA DEP Method 1 S-3/GW-1 and Method 1 S-3/GW-3 Cleanup Standards.

This report describes the remediation of the FS-12 source area as defined in the Final Action Memorandum (*ASI 1996*).

2. BACKGROUND

MMR is located in western Cape Cod immediately southeast of the Cape Cod Canal, in parts of the towns of Bourne, Falmouth, Sandwich, and Mashpee, covering approximately 22,000 acres. Portions of MMR have been used for military purposes since 1911. Since 1935, MMR has been used for U.S. Army training maneuvers, military aircraft operations, maintenance, and support. Six military units currently operate at MMR: Massachusetts Army National Guard (Camp Edwards), Massachusetts Air National Guard (Otis Air National Guard Base [ANGB]), U.S. Air Force, U.S. Coast Guard, Veterans Administration, and 1st Battalion 25th Marines.

In July 1989, USEPA proposed MMR for inclusion on the federal Superfund National Priorities List (NPL). USEPA formally added MMR to the NPL on November 21, 1989. Therefore, MMR is subject to the special provisions for federal facilities under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980. On July 17, 1991, the NGB entered into an Interagency Agreement (IAG) with USEPA Region I that outlines cleanup policies and procedures at MMR. In early 1996, AFCEE assumed management of the MMR program.

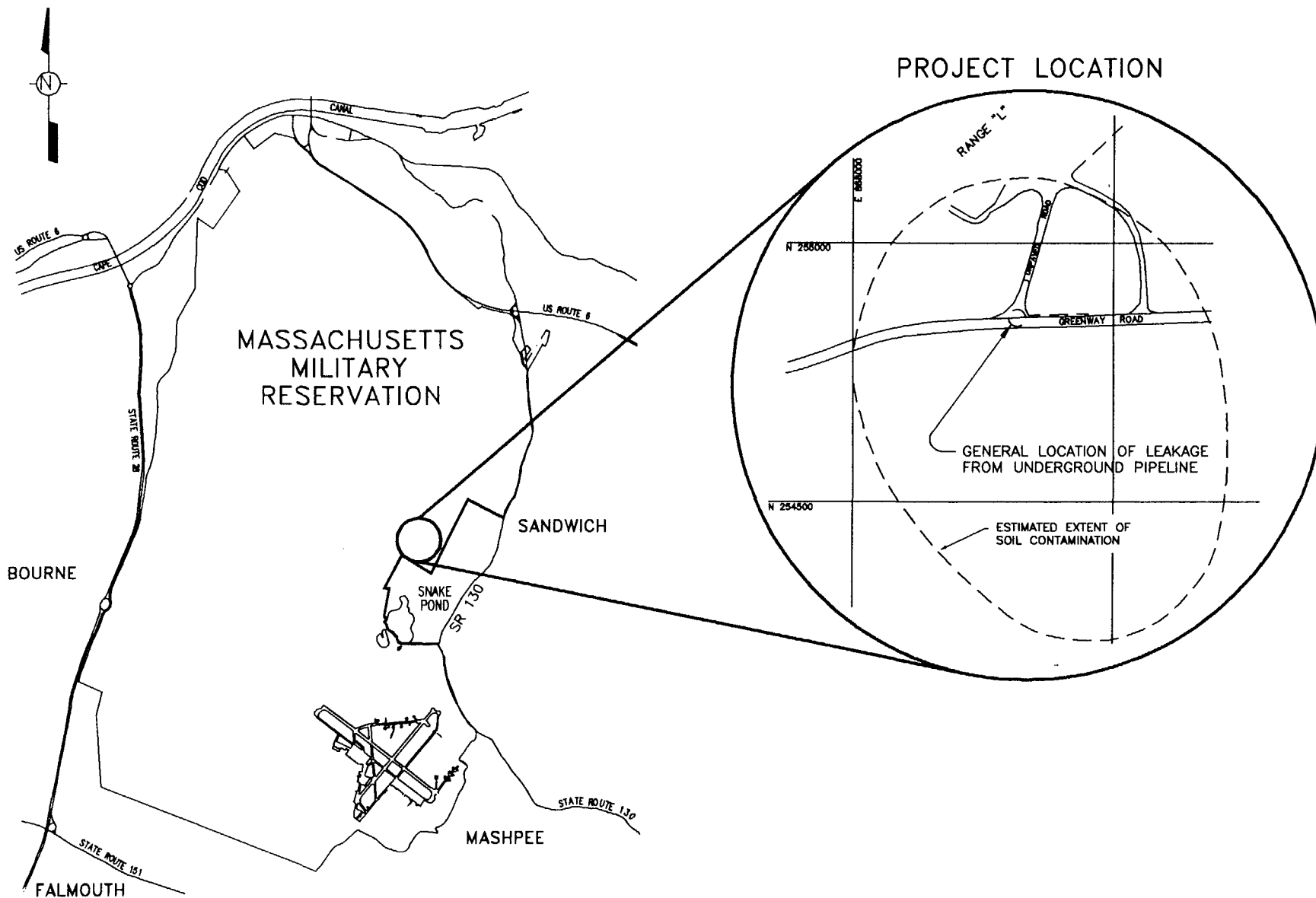
2.1 History and Selected Remedy

AOC FS-12 is the location of a leak in a now abandoned fuel pipeline along the base border in the Town of Sandwich. As shown in Figure 2.1, AOC FS-12 is located west of Route 130 and north of Snake Pond in the Town of Sandwich. AOC FS-12 is in a wooded area that can be reached from State Route 130 by way of Greenway Road. The nearest public access area downgradient of the FS-12 source area is Camp Good News, a youth recreation and camping facility located in the rural setting immediately east of the boundary. Snake Pond and wetlands are located to the south of AOC FS-12.

The abandoned fuel pipeline runs along the north shoulder of Greenway Road. The leak occurred at or near the intersection of Greenway Road and an unpaved road providing access to artillery range "L" shown in Figure 2.1. The pipeline carried both jet fuel and aviation gasoline during its use from 1965 to 1973. The leak was reported to have occurred in 1972; however, free product was not discovered in the area until December 1992. Monitoring wells were installed during January and February of 1993 to estimate the extent of floating/free product detected in monitoring wells WT-11 and WT-13 during remedial investigation (RI) field activities conducted during December 1992 (*ASI 1995*). The areal extent of floating/free product was initially defined as approximately 7.8 acres (Appendix D). However, based on additional characterization information collected during performance of pilot studies in 1993, the FS-12 source area was subsequently redefined to be approximately 11 acres of contaminated vadose zone soil, groundwater, and floating product (Figure 2.2) (*ASI 1994*).

Samples of free product collected during 1992 RI groundwater sampling activities were sent to both military and civilian laboratories (Weston on-site field lab, Brooks Air Force lab, and United States Coast Guard Oil Identification lab) for chemical analysis and evaluation. Results of the analyses indicated predominately a diesel-like fuel, very likely jet propulsion fuel (JP-4), with traces of other components that are more characteristic of a gasoline-based fuel.

Data collected during the January-February 1993 well installation activities were used to predict existing quantities of recoverable and residual product volumes. The SPILLCAD and ARMOS-Lite software packages developed by Environmental Systems and Technologies, Inc. were used to model the



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FIGURE 2.1
PROJECT LOCATION MAP

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FS-12 source area. Numerical modeling of the FS-12 source area indicated an estimated range of total volume of recoverable and residual fuel of 4,400 – 93,600 gallons (Appendix E). A lack of actual aquifer properties such as hydraulic conductivity, porosity, and specific yield added uncertainty to the modeling results. Aquifer properties were varied in each of ten modeling scenarios to evaluate the predicted range of recoverable and residual fuel. In three of the ten scenarios, the estimated quantity of recoverable and residual fuel was approximately 70,000 gallons.

Pilot studies were conducted at the FS-12 source area during August and September of 1993 to provide information concerning the effectiveness and implementability of proposed AS/SVE and free product recovery technologies. Based on information collected during the pilot studies and other data available from previous RI activities, the vertical extent of subsurface soil petroleum contamination was estimated to be a 10ft to 20ft layer in the vicinity of the water table. The estimated areal extent of contamination was defined to be approximately 11 acres (Figure 2.2). The estimated amount of recoverable and residual hydrocarbons in the soil was determined to be 395,000 pounds. This estimate was based on an assumption that 75% of the 70,000 gallons of fuel still existed in the 11-acre area, just prior to full-scale operation of the AS/SVE system.

Analysis of groundwater samples taken during the product recovery pilot study confirmed that the groundwater underlying the contaminated soil in AOC FS-12 had also been impacted by the pipeline leak. Samples were analyzed for benzene, toluene, ethylbenzene, and xylenes (BTEX) and EDB, which are typical fuel components. Previous investigations at the FS-12 source area indicated similar fuel components (*ASI 1995*).

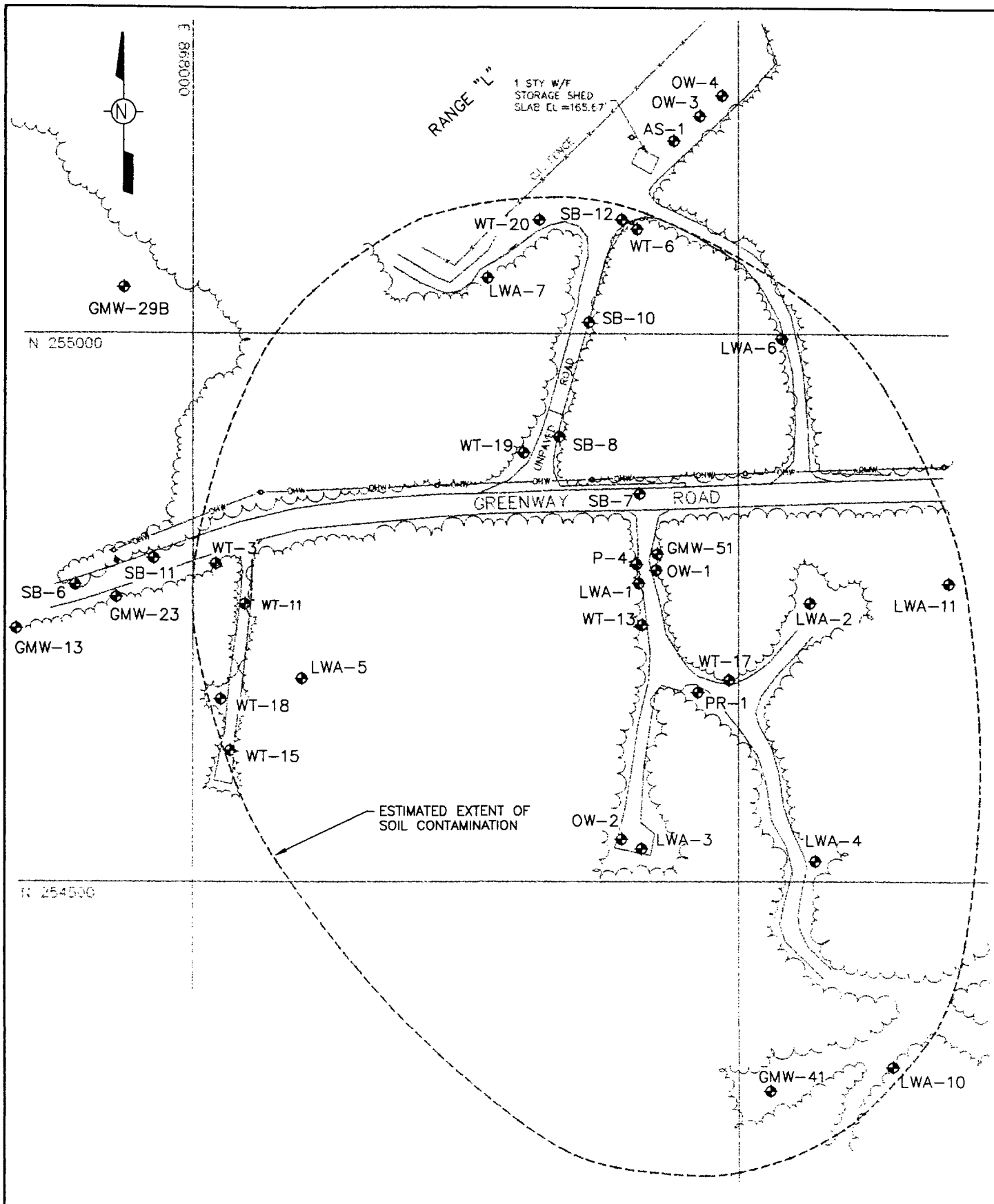
Final plans and specifications for remediation of the FS-12 source area, via a combined AS/SVE system, were issued by Commodore Advanced Sciences, Inc. (CAS) [formerly known as Advanced Sciences, Inc. (ASI)] (*ASI 1994*). The NGB awarded the contract for installation and operation of the FS-12 remediation system to DGC, Inc.

2.2 System Requirements for Construction, Start-Up and Operation, and Closure

A general summary of work as presented in the technical specifications (*ASI 1994*) and Action Memorandum (*ASI 1996*) is outlined below. This summary provides a basic understanding of the project requirements with which to evaluate subsequent sections of this document.

Activities required to implement the proposed action included the following:

- equipment purchase/lease and mobilization;
- site clearing;
- drilling and construction for 23 AS wells and 23 SVE wells;
- installation of underground piping;
- treatment system equipment installation;
- upgrade of existing area power from single-phase to three-phase;
- system start-up and operation;
- closure sampling/analysis per Action Memorandum (*ASI 1996*);
- waste management including but not limited to disposition of all secondary waste streams;
- demobilization of system equipment;
- restoration of site to original condition; and
- final approval of removal action summary report.



LEGEND

● MONITORING WELL

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SCALE IN FEET

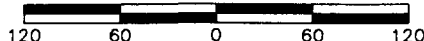


FIGURE 2.2 ESTIMATED EXTENT OF SOIL CONTAMINATION

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3. PROJECT ORGANIZATION

The contract specifications required the General Contractor, DGC, Inc., to execute specific, detailed, and specialized activities relative to construction and operation of the FS-12 source area remediation system and implement appropriate health and safety and quality control procedures. The following section outlines the information, planning, and review requirements for these efforts.

3.1 Contractual Relationships

The FS-12 Source Area remediation contract was executed by the NGB and the General Contractor, DGC, Inc. DGC, Inc. employed several subcontractors and vendors during project execution:

- LaFramboise Well Drilling, Inc. was subcontracted to implement the drilling and well installation phases of the project.
- Atlantic® Environmental Technologies, Inc. of Sandwich, Massachusetts was subcontracted to provide monitoring and data evaluation services during operation of the remediation system. All off-site analytical work, including analysis of groundwater and subsurface soil samples, was subcontracted through Atlantic®.
- Professional land survey services were provided by CapeSurv, Inc. of Hyannis, Massachusetts.

Technical support services to AFCEE were subcontracted to CAS through the U.S. Department of Energy's Oak Ridge Office Advanced Infrastructure Management Technologies (AIMTECH, formerly known as HAZWRAP) and were provided on an as-needed basis.

3.2 Project Plans

Technical specifications and construction drawings were prepared and issued by CAS. DGC, Inc. was required to provide special project plans outlining the intended approach to the project relative to specific task execution, health and safety, controlling spills of hazardous materials and substances, sampling and analysis, disposal and/or treatment of regulated and non-regulated wastes, and QC procedures.

DGC, Inc. prepared a Remedial Action Work Plan, Health and Safety Plan, and Quality Assurance/Quality Control Plan for both Phase I and Phase II of the project. Phase I involved construction of the remediation system while Phase II involved system operation and system closure. All project documentation is on file at the AFCEE/MMR IRP offices at Otis ANGB.

4. SYSTEM DESCRIPTION AND PERFORMANCE REQUIREMENTS

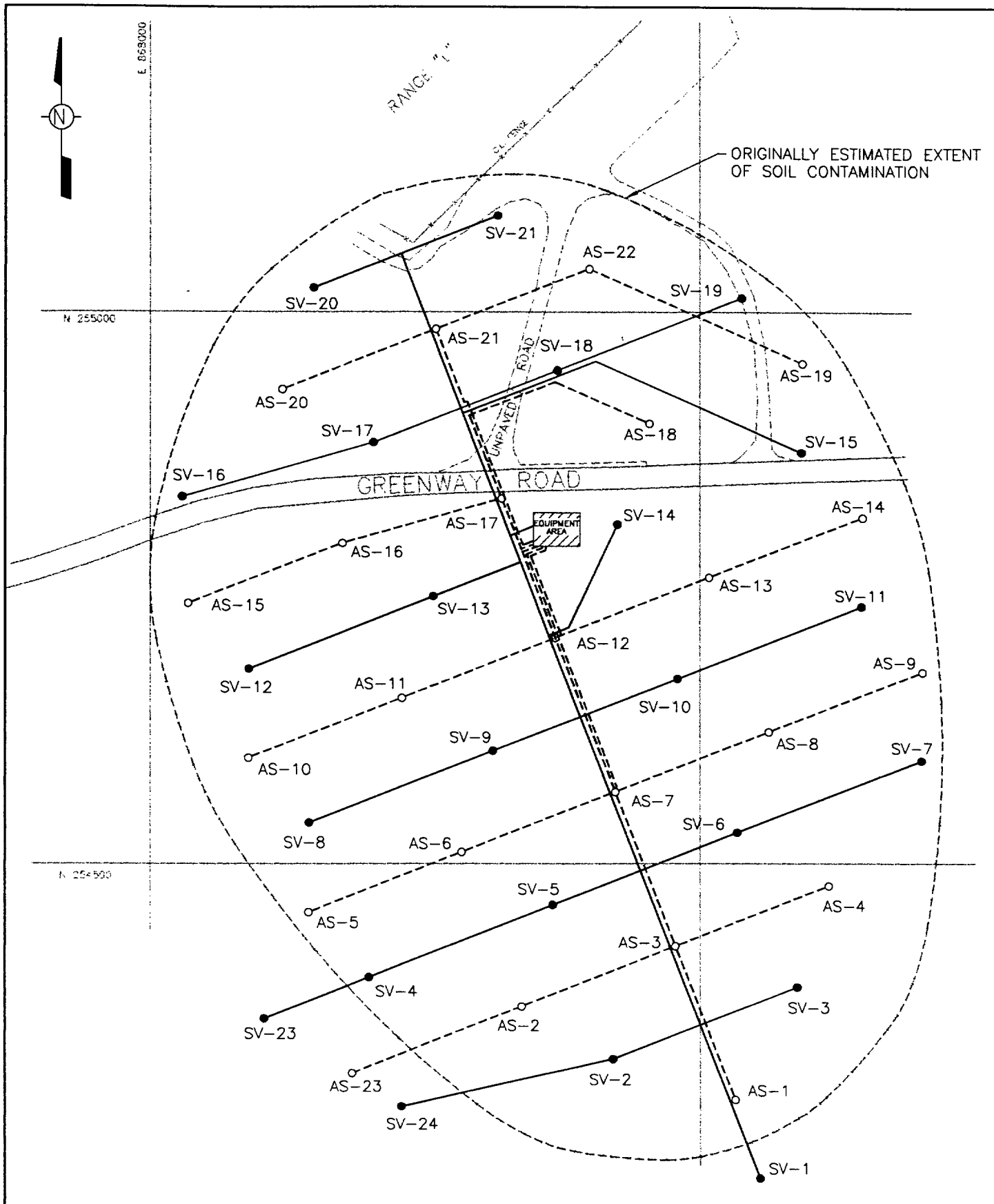
The removal action utilized an AS/SVE system to achieve *in situ* air stripping and biodegradation of petroleum-derived hydrocarbons from subsurface soils in the FS-12 source area. Compressed air was supplied through 23 AS wells, and withdrawn from the contaminated soil region by 23 SVE wells (Figure 4.1). Oxygen in the air activated microbial communities in the soils, which, in turn, enhanced the contaminant biodegradation process. The relative level of biodegradation was qualitatively determined by increased carbon dioxide levels detected in the SVE wells during operation of the system. The number of wells and their spacing were based on pilot studies conducted on site during August/September 1993, when the radius of influence and other design parameters, such as flow rates and vacuum and injection pressures, were experimentally determined (ASI 1994). The area of influence of the SVE wells encompassed the estimated AOC, where the wells were positioned to maintain a net negative pressure over this area of influence during operation of the AS/SVE system. This net negative pressure eliminated the potential for off-site migration of vapors generated as a result of the AS/SVE system.

During the free product recovery effort conducted by DGC, Inc. from January 23, 1996 through February 9, 1996, SVE wells SV-1 through SV-21 and wells OW-2, WT-6, WT-11, WT-13, WT-15, WT-17, WT-18, WT-19, and WT-20 were sampled for free product using an oil/water interface probe. Free product was detected in ten (10) SVE wells and wells WT-11, WT-13, WT-17, and WT-19. Based on these results, pumping was conducted to remove as much free product as possible. Approximately 75 gallons of liquid were removed during the product recovery effort.

This information, in addition to data collected during previous investigations, indicated the need to verify the extent of soil contamination in the southwest quadrant of the source area. Wells SV-23 and SV-24 were installed in July 1997. SVE well SV-22 was originally proposed as part of this effort but was later removed from the design and never built. Wells SV-23, SV-24, and GMW-100 were sampled in July 1997 with elevated levels of EDB and BTEX detected. Based on these analytical results, wells SV-23 and SV-24 were connected to the SVE system, and new AS well AS-23 was installed to support source area groundwater and soil remediation in the southwest quadrant.

Petroleum-derived contaminants in the soil vapor drawn from the SVE wells included BTEX and EDB. Vapor-phase BTEX contaminants were destroyed thermally by passing the soil vapor through a catalytic oxidation unit. Since EDB is not readily removed by thermal oxidation, the potential for airborne release of trace amounts of EDB existed. To prevent the airborne release of EDB, gases from the catalytic oxidation unit were then passed through a carbon adsorption unit. A schematic flow diagram of the SVE treatment system is shown in Figure 4.2.

The SVE system was originally designed to achieve a flow rate of 3,500 standard cubic feet per minute (scfm). Standard units are based on an atmospheric temperature of 68°F and pressure of 14.7 pounds per square inch absolute (psia). During the initial operational period of the system, the airflow measuring station was transmitting flow rates of approximately 2,500 actual cubic feet per minute (acfm) to the system computer. Based on the flow rates measured by the system computer being significantly less than the design flow rate, CAS personnel measured air flow velocities in SVE wells SV-1 through SV-21, and various locations throughout the off-gas treatment system, during the week of June 10- 14, 1996. It was determined that the location of the airflow measuring station in the off-gas piping prior to the catalytic oxidation unit was causing inaccurately low system flow rates. Appendix F contains details of the field activities and recommendations to accurately measure flow rates per guidance provided in 40 CFR 60, USEPA Methods 1 and 2.



LEGEND

- AIR SPARGING WELL
- SOIL VENTING WELL
- AIR SPARGING PIPE
- SOIL VENTING PIPE

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SCALE IN FEET

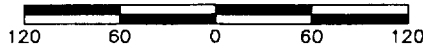
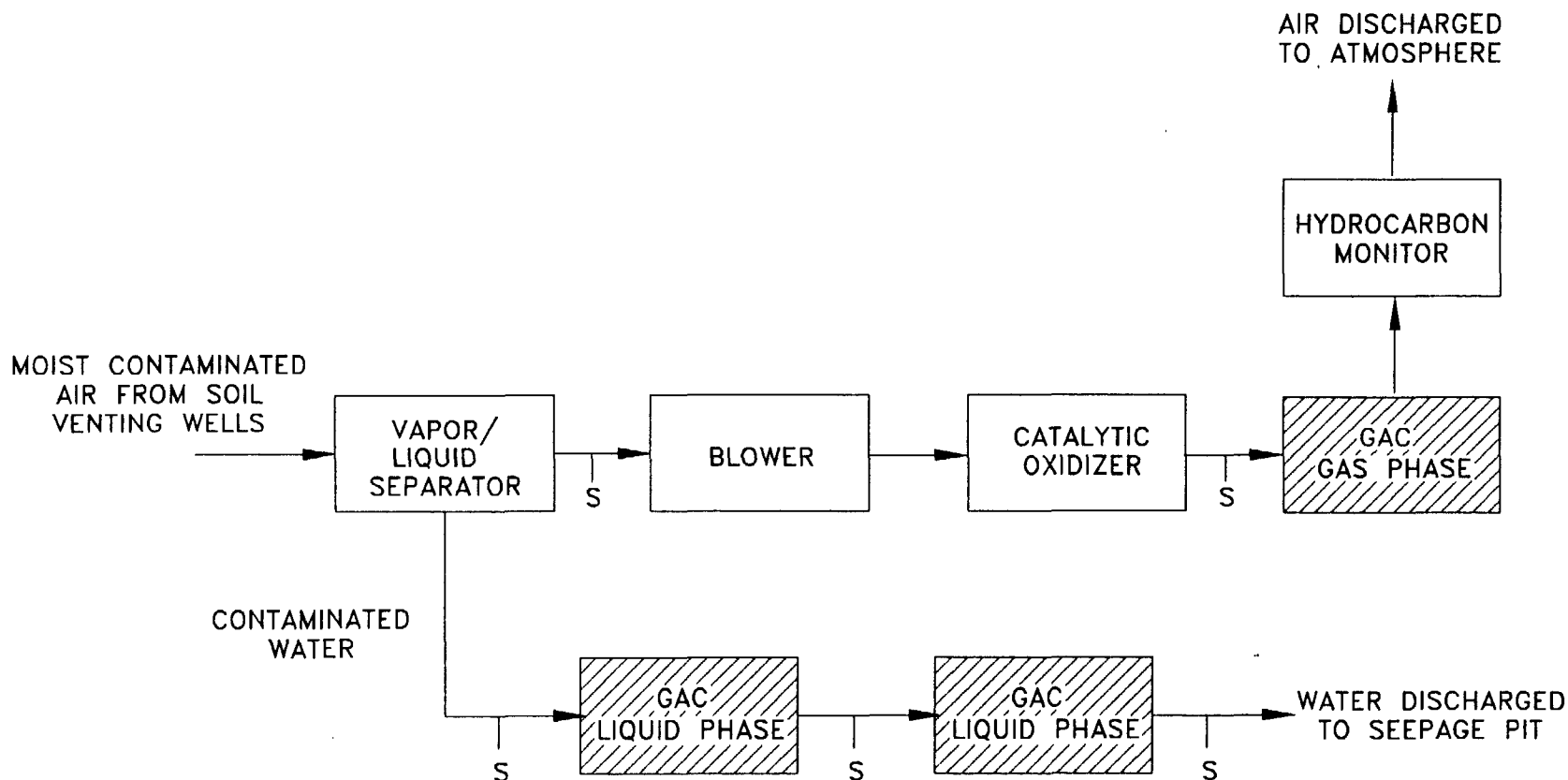


FIGURE 4.1
AIR SPARGING/SOIL VAPOR
EXTRACTION WELLS LAYOUT
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GAC = GRANULAR ACTIVATED CARBON
S = SAMPLING PORT

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FIGURE 4.2
SOIL VAPOR TREATMENT
FLOW DIAGRAM

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DATE: 6-8-99

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Atlantic® Environmental Technologies, Inc. of Sandwich, Massachusetts provided monitoring and data evaluation services to DGC, Inc. during operation of the remediation system. On September 13, 1996, Atlantic® conducted actual system flow rate measurements in accordance with 40 CFR 60, USEPA Methods 1 and 2. Results of these measurements indicate the average soil vapor flow rate to the system was 3,061 acfm (2,791 scfm). Actual system flow rate was determined in a straight run of 12 inch diameter piping between the air/water separator and the system filter located on the inlet side of the system blower. Actual flow rate at this location was based on a vacuum pressure of 36 inches of water and a temperature of 59°F. Details of the flow rate measurement activities and associated calculations are included in Appendix G.

The actual system flow rate, determined by the September 13, 1996 field measurements, indicated the actual flow rate was approximately 80% of the design flow rate. A review of the MODFLOW Model (ASI 1994) used to design the AS/SVE system indicated that the reduced flow rates would not affect the performance of the system. Assuming a linear reduction of pressure relative to flow rate, pressures shown on the pressure distribution curves (without air sparging) located in the system design calculations (ASI 1994) were conservatively reduced by 33% (Appendix H). This reduction in vacuum pressure was subtracted from the pressures shown on the pressure distribution curves associated with operation of each leg of the AS/SVE system (Appendix H). Based on this analysis, although there was a positive pressure increase within the area of influence of the AS system due to the decreased SVE system flow rate during operation of the AS/SVE system, a net negative pressure continued to be maintained over the original subsurface soil contamination area defined by Figure 2.2.

Emissions of volatile organic compounds (VOCs) to ambient air, resulting from remedial actions at sites, are regulated by the MA DEP's Bureau of Waste Prevention (BWP). Guidance is provided per MA DEP Policy # WSC-94-150, *Off-Gas Treatment of Point-Source Remedial Air Emissions*. The destruction efficiency requirement was at least 95% as stated in the system specifications (ASI 1994), in order to satisfy MA DEP's BWP requirements specified in the guidance document. Operational data, provided in Section 8, indicate air emission requirements were satisfied during operation of the AS/SVE system.

Destruction of gross VOCs by catalytic oxidation is less expensive per unit volume than adsorption by activated carbon, provided gross VOC concentrations in the soil vapor are initially relatively high. As remediation progressed, gross VOC concentrations decreased and eventually fell below an economic "break even" point, whereupon carbon adsorption became the less expensive per unit volume treatment method. This "break even" point was calculated to be approximately 5 ppm gross VOCs. Therefore, pursuant to an agreement reached between AFCEE, USEPA, and MA DEP on June 13, 1997 (Appendix K), the catalytic oxidation unit was turned off and soil vapor was treated by the vapor phase carbon unit only.

MA DEP groundwater and soil cleanup standards are stipulated in 310CMR40.0974 and 40.0975. Contaminants detected at the FS-12 Source Area, and their applicable soil and groundwater cleanup standards, are shown in Table 4.1, as specified in the Final Action Memorandum (ASI 1996). The primary goal of the removal action was to meet these groundwater and soil cleanup standards in the source area.

The source area groundwater is identified as Categories GW-1 and GW-3, in accordance with 310 CMR 40.0932, due to its up-gradient location relative to the Town of Sandwich drinking water supply. The source area soil in the vicinity of the water table (located approximately 90 feet below grade) is identified as Category S-3 in accordance with 310 CMR 40.0933, due to its depth below grade. The soil is characterized as "isolated" due to its location being much greater than 15 feet below grade.

Table 4.1

MA DEP Method 1 Cleanup Standards

Chemical	Groundwater Standard ** (ppb)	Soil Standard * (ppm)
Benzene	5	10
Ethylbenzene	700	80
Toluene	1,000	90
Total Xylenes	10,000	800
TPH	1,000	5,000
Ethylene Dibromide	0.02	0.005
VPH (C5-C8)	400	500
VPH (C9-C12)	4,000	5,000
VPH (C9-C10)	200	100
EPH (C9-C18)	4,000	5,000
EPH (C19-C36)	5,000	5,000
EPH (C11-C22)	200	200

NOTES:

ppb = parts per billion

ppm = parts per million

TPH = total petroleum hydrocarbons

*** Method 1 S-3/GW-1 and Method 1 S-3/GW-3**

Note: Values shown in Table 4.1 are associated with Method 1 S-3/GW-1 Standards. This is conservative since values associated with Method 1 S-3/GW-3 standards are higher.

**** Method 1 GW-1 and Method 1 GW-3**

Note: Values shown in Table 4.1 are associated with Method 1 GW-1 Standards. This is conservative since values associated with Method 1 GW-3 standards are higher.

5. REMEDIATION ACTIVITIES

Remediation activities were estimated to take two years to remove 395,000 pounds of residual hydrocarbons. Remediation time was based on theoretical design calculations (*ASI 1994*). The actual system operating time was based on satisfying closure criteria specified in the Final Action Memorandum (*ASI 1996*). A summary of the originally planned and actual operation schedules is presented in Table 5.1. There were no significant deviations from the planned operation schedule.

An estimated total of 44,579 pounds of product was removed by the AS/SVE from the source area during a 29-month period, as summarized in Table 5.2. The AS/SVE system removed approximately 11% of the estimated 395,000 pounds of residual hydrocarbons. The off-gas treatment system catalytic oxidizer in series with a carbon adsorption unit maintained an average destruction efficiency of greater than 95% while the system was operational. A critique of the original spill volume estimates (4,400 gallons to 93,000 gallons) and discussion of additional fate mechanisms is included in Appendix J.

Atlantic® generated thirty monthly reports, containing detailed operational and monitoring information. Copies of these reports are on file at the AFCEE/MMR IRP offices at Otis ANGB.

TABLE 5.2
SUMMARY OF ESTIMATED QUANTITY OF REMOVED PRODUCT
October 1995 through February 1998

FS-12 Product Recovery System
Massachusetts Military Reservation

Date	Quantity Removed		Total Removed		Comments
	pounds	gallons	pounds	gallons	
1995					
November	1,788.65	276	1,788.65	276	
December	253.94	39	2,042.59	315	
1996					
January	3,693.63	569	5,736.22	884	
February	3,702.59	570	9,438.81	1,454	
March	13,105.96	2019	22,544.77	3,474	
April	0	0	22,544.77	3,474	system shutdown on 4/2 due to iron fouling
May	0	0	22,544.77	3,474	scheduled shutdown
June	6,403.73	987	28,948.50	4,460	
July	784.5	121	29,733	4,581	
August	0	0	29,733	4,581	system not operating due to modification
September	9,411.89	1450	39,144.89	6,031	of heat exchanger water supply
October	1972.11	304	41,117	6,335	
November	0	0	41,117	6,335	scheduled shutdown
December	507	78	41,624	6,413	
1997					
January	269	41	41,893	6,455	
February	0	0	42,220	6,505	scheduled shutdown
March	327	50	42,835	6,600	
April	114	17	42,949	6,617	
May	81	12	43,030	6,630	
June	103	16	43,133	6,646	
July	0	0	43,133	6,646	scheduled shutdown
August	145	22	43,278	6,668	
September	83	13	43,361	6,681	
October	205	31	43,566	6,706	
November	264	41	43,830	6,747	
December	166	26	43,996	6,772	
1998					
January	73	11	44,069	6,783	
February	452	70	44,521	6,853	
March	58	9	44,579	6,862	system shutdown on 2/3
April	0	0	44,579	6,862	

6. DEVIATIONS FROM THE ACTION MEMORANDUM

Table 6.1 includes changes made to the original AS/SVE system plans and specifications (*ASI 1994*) and associated rationale. No major changes to the original design were required. With the exception of the southwest quadrant of the originally estimated extent of the source area, the extent of contamination was accurately defined with limited characterization data. The key to the successful operation of the system, and limited design changes required over its operational life, was the flexibility integrated into the original design allowing appropriate adjustments to system flow rates, and the ability to shut down individual SVE wells and AS well legs based on changing subsurface soil conditions, groundwater conditions, free product volumes and contaminant concentrations.

Table 6.1
Design Changes Made During Construction/Operation
of the Source Area Remediation System

Design Change	Rationale
1. 2-inch stainless-steel screen for typical AS well called out on Drawing No. ASSV-6, Rev. 0, changed to Spargepoint™ microporous bubblers.	Less likely to create preferential pathways within aquifer, resulting in a more even distribution of air within soil below water table.
2. Addition of AS wellhead check valves.	Minimize possibility of clogging bubblers by back flow of well water that might contain iron precipitated by internal airflow.
3. Change-out in AS piping from sch.40 galvanized iron to sch.80 galvanized iron pipe (from compressor to 150 ft) and sch.80 PVC pipe (remainder of AS piping system).	Constructability was main reason for change. Temperature of air will drop sufficiently within galvanized iron piping not to degrade PVC piping. Also, compressed air system is oil-free; therefore, PVC piping will not be structurally affected.
4. Expansion joints called out on Drawing No. ASSV-6, Rev. 0 in AS wellhead and SVE wellhead details was eliminated.	Piping was installed with horizontal variations near wellhead to allow for differential ground movement.
5. AS/SVE wellhead details shown on Drawing ASSV-6, Rev. 0 modified to include full-size tee for sampling.	Provided 43 additional locations within source area to perform groundwater and air sampling.
6. Demtrol catalytic oxidation system blower re-sized to provide 3,500 scfm at 70° F and 61 inch water column pressure.	Allow for added discharge side head losses from heat exchanger, Carbtrol vapor-phase filter, and associated ductwork.
7. Addition of vapor-phase carbon unit and air/water heat exchanger on discharge side of catalytic oxidation system.	Additional air treatment required due to concern that EDB is not readily removed by thermal oxidation. Air/water heat exchanger required to lower temperature of soil vapor prior to passing through carbon unit.
8. 30 ft x 40 ft pre-fabricated building detailed on Drawing Nos. ASSV-10, Rev. 0 through ASSV-15, Rev. 0 replaced with one 8 ft x 30 ft sparging trailer and one 8 ft x 32 ft treatment trailer.	Primary treatment system equipment and components become mobile, enabling the system to possibly be relocated and used at other sites. Also eliminates potential surveillance and maintenance costs and decontamination and dismantlement of more permanent facility.
9. Addition of computer system to monitor the FS-12 remediation system operations.	Provides a continuous record of system operational data to allow a more credible, defensible comparison of actual versus predicted performance. Also provides an added level of safety by automatically shutting down system when a system fault is detected and notifying emergency contacts via an auto-dialer.
10. Installed new SVE wells SV-23 and SV-24 and new AS well AS-23 in southwest quadrant of source area.	The free product recovery effort conducted by Dave Gardner Contractors, Inc., from 1/23/96 to 2/09/96, and data collected during previous investigations indicated the potential for contamination past the originally defined southwest quadrant of the source area. Additional wells were installed to capture this potential contamination.

7. WASTE MANAGEMENT AND TRANSPORTATION ACTIVITIES

Wastes generated as a result of this removal action are specified in Table 7.1 below. The trailers, associated equipment, and Carbtrol liquid-phase carbon units are currently stored at the Unit Training Equipment Storage (UTES) facility, located approximately one mile west of the FS-12 source area off of Greenway Road.

TABLE 7.1
SUMMARY OF SECONDARY WASTE GENERATION

SECONDARY WASTE	QUANTITY	TREATMENT/DISPOSITION
1) Development water/purge water for SV wells and decontamination fluid.	Two 300 gallon poly tanks	Treat/dispose at CS-4 Groundwater Treatment Facility.
2) Water (with chlorine) used to clean heat exchanger and associated piping and AS wells (microporous bubblers).	One 300 gallon poly tank	Treat/dispose at CS-4 Groundwater Treatment Facility.
3) Condensation from Off-Gas Treatment System.	100 gallons	Liquid phase carbon with ground discharge.
4) Contaminated drill cuttings.	Sixty-eight 55-gallon drums	FTA-1 On-Site Thermal Treatment Program.
5) Vapor Phase Carbon	9000 pounds	CETCO, the vapor phase carbon supplier, vacuumed out spent carbon from a 3000 pound vessel, three times, then transported the spent carbon to a permitted regeneration facility.
6) Fuel pumped from SVE wells during the period of January 23, 1996 through February 9, 1996.	75 gallons	Dispositioned by Base Environmental Specialist for the 102 nd Fighter Wing through the Defense Reutilization Marketing Office at Newport Navy Base, Rhode Island.

8. SYSTEM MONITORING AND PERFORMANCE

A computer system was placed into operation on March 5, 1996 to provide continuous monitoring of the AS/SVE system. Parameters monitored included various temperature readings, influent and effluent VOC concentrations, and the destruction percentages. Four readings were obtained by the monitoring system daily at 4:30 a.m., 10:30 a.m., 4:30 p.m. and 10:30 p.m. Each monthly report prepared by Atlantic® included the daily monitoring readings obtained while the AS/SVE system was in operation. Daily monitoring of influent and effluent off-gases was performed to continuously evaluate the performance of the off-gas treatment system in order to recommend configuration changes and/or carbon change-out as needed. A monthly summary of the average daily monitoring data has been included as Table 8.1.

8.1 Monthly Influent/Effluent Sampling for BTEX and EDB

During operation of the AS/SVE system, influent and effluent off-gas samples were collected and analyzed for BTEX and EDB by an off-site laboratory using NIOSH Method 1501 for BTEX, and NIOSH Method 1008 for EDB. As shown in Table 8.2, the off-gas treatment system generally maintained a greater than 95 percent destruction efficiency while removing contaminants from the FS-12 source area.

8.2 Active and Static VOC Monitoring of SVE Wells

Total VOC concentrations were measured monthly in each SVE well, using a photoionization detector (PID). Detailed sampling procedures are included in Appendix B of the Final Action Memorandum (*ASI 1996*). The recorded concentrations of VOCs in each SVE well are shown in Table 8.3. Concentrations were detected from 0 ppm to 390 ppm.

Readings from both static and active conditions are shown. The VOC concentration before each start-up of the SVE system determined the static rebound function. The VOC concentration after one pore volume was purged from the radius of influence of each extraction well (four days after each start-up) determined the dynamic or active rebound function. Recording these two values monitored individual extraction well performance. This information was required to establish a basis for satisfying specific closure criteria included in the Final Action Memorandum (*ASI 1996*).

8.3 Carbon Dioxide (CO₂) and Oxygen (O₂) Monitoring of SVE Wells

On May 17, 1996, after an approximately 45-day shutdown period, CO₂ and O₂ concentrations were measured in each SVE well using calibrated CO₂ and O₂ meters. Detailed sampling procedures are included in Appendix B of the Final Action Memorandum (*ASI 1996*). Results of the CO₂ and O₂ sampling are included in Atlantic®'s Monthly Report, dated April 23, 1996 through May 22, 1996.

In all SVE wells, lower O₂ percentages were directly proportional to higher CO₂ percentages. The highest O₂ and lowest CO₂ percentages were measured in SVE wells along the northern (SV-21 and SV-20), southern (SV-1, SV-2 and SV-3) and eastern (SV-7, SV-11 and SV-19) edges of the well field. Conversely, SVE wells near the center of the well field (SV-5, SV-9, SV-10 and SV-14) had the lowest O₂ and highest CO₂ percentages. All wells where free product had been detected had O₂ percentages below 19.0% and CO₂ percentages above 0.5%. For reference, ambient air typically is 20.6% O₂ and 0.033% CO₂.

TABLE 8.1
SUMMARY OF DAILY MONITORING DATA (Monthly Averages) 1995-1998

FS-12 Product Recovery System
Massachusetts Military Reservation

DATE	INFLUENT TEMP. °F	AMBIENT TEMP. °F	GROSS VOCs			
			INFLUENT- PPM	HEAT EXCHANGER OUT- PPM	CARBON OUT- PPM	DESTRUCTION PERCENT
Mar-96	49.45	43.40	2877.02	68.90	64.57	97.80
Apr-96	44.50	38.25	2034.45	66.20	76.70	96.20
May-96	60.20	58.40	858.80	3.10	0.50	99.90
Jun-96	56.90	63.44	877.66	38.82	15.74	98.20
Jul-96	system not operational for entire month					
Aug-96	60.25	67.40	665.00	30.50	17.70	97.30
Sep-96	63.73	64.83	302.70	3.76	1.03	99.70
Oct-96	61.91	55.52	363.15	5.53	1.50	99.60
Nov-96	59.80	49.32	145.30	2.075	1.05	99.30
Dec-96	58.10	42.60	53.30	0.25	0.22	99.60
Jan-97	54.97	35.30	56.72	5.25	0.32	99.40
Feb-97	45.88	38.62	76.38	7.42	2.74	96.40
Mar-97	45.34	38.56	61.74	4.58	0.50	99.20
Apr-97	45.50	41.80	68.15	5.80	0.45	99.30
May-97	46.70	54.30	25.12	1.55	0.13	99.50
Jun-97	48.10	61.34	18.40	6.32	1.24	93.20
Jul-97	51.67	72.65	13.77	13.22	2.77	79.90
Aug-97	51.24	65.40	35.56	33.44	2.88	91.90
Sep-97	50.10	59.00	53.30	49.80	3.53	93.40
Oct-97	48.23	55.07	64.65	57.90	8.65	86.60
Nov-97	46.88	45.52	51.10	5.90	1.60	96.90
Dec-97	45.80	39.60	114.05	16.05	1.75	98.50
Jan-98	45.05	37.32	25.25	3.47	3.10	87.70
Feb-98	44.90	41.20	370.50	44.40	8.70	97.70

Notes: Automated daily monitoring system installed March 1996.

Four daily readings were obtained while system in operation (4:30 a.m., 10:30 a.m., 4:30 p.m. and 10:30 p.m.)

TABLE 8.2
SUMMARY OF AIR POLLUTION CONTROL UNIT LABORATORY RESULTS

Monthly Monitoring
October 1995 through February 1998

FS-12 Product Recovery System
Massachusetts Military Reservation

Date	Influent Analysis						Effluent Analysis						Destruction Efficiency percent
	Total BTEX mg/m ³	Benzene ppm	Toluene ppm	EB * ppm	Total Xylenes ppm	EDB * ppb	Total BTEX mg/m ³	Benzene ppm	Toluene ppm	EB * ppm	Total Xylenes ppm	EDB * ppb	
1995													
13-Oct	360	100	260	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	> 95
26-Oct	170	BDL	170	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	> 95
30-Oct	210	BDL	210	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	> 95
2-Nov	430.8	BDL	410	BDL	20.8	BDL	BDL	BDL	BDL	BDL	BDL	BDL	> 95
9-Nov	96.3	BDL	88	BDL	8.3	BDL	BDL	BDL	BDL	BDL	BDL	BDL	> 95
22-Nov	331	BDL	300	BDL	31	BDL	0.32	BDL	0.32	BDL	BDL	BDL	99.8
December	191.8	BDL	170	BDL	21.8	BDL	BDL	BDL	BDL	BDL	BDL	BDL	> 95
1996													
February	370	BDL	340	BDL	30	BDL	4.6	BDL	4.6	BDL	BDL	BDL	98.8
March	160	BDL	BDL	BDL	42.5	BDL	2.3	BDL	BDL	BDL	0.61	BDL	98.6
June	409	BDL	71.7	4.4	27.6	BDL	BDL	BDL	BDL	BDL	BDL	BDL	> 95
September	1.625	0.5	BDL	BDL	BDL	0.107	BDL	BDL	BDL	BDL	BDL	BDL	> 95
October	7.4	0.3	0.2	0.82	0.64	BDL	BDL	BDL	BDL	BDL	BDL	BDL	> 95
November	5.5	0.207	0.101	0.362	0.694	0.092	BDL	BDL	BDL	BDL	BDL	BDL	> 95
1997													
January	0.806	0.069	BDL	BDL	0.101	NA	BDL	BDL	BDL	BDL	BDL	NA	> 95
February	0.189	0.158	BDL	BDL	0.218	BDL	BDL	BDL	BDL	BDL	BDL	BDL	> 95
March	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	> 95
May	0.377	BDL	BDL	BDL	0.87	BDL	BDL	BDL	BDL	BDL	BDL	NA	> 95
June	BDL	BDL	BDL	BDL	BDL	BDL	NA	BDL	BDL	BDL	NA	NA	> 95
July	BDL	BDL	BDL	BDL	BDL	BDL	NA	BDL	BDL	BDL	NA	NA	> 95

TABLE 8.2
SUMMARY OF AIR POLLUTION CONTROL UNIT LABORATORY RESULTS
 Monthly Monitoring
 October 1995 through February 1998

FS-12 Product Recovery System
Massachusetts Military Reservation

Date	Influent Analysis						Effluent Analysis						Destruction Efficiency percent
	Total BTEX mg/m ³	Benzene ppm	Toluene ppm	EB * ppm	Total Xylenes ppm	EDB * ppb	Total BTEX mg/m ³	Benzene ppm	Toluene ppm	EB * ppm	Total Xylenes ppm	EDB * ppb	
1997													
August	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	> 95
September	0.03	0.03	BDL	BDL	BDL	BDL	BDL	0.02	BDL	BDL	BDL	BDL	33.3 ¹
November	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	> 95
1998													
January	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	> 95

Notes: * EB = ethylbenzene
 * EDB = ethylene dibromide

Samples analyzed for BTEX via NIOSH Method 1501 and EDB via NIOSH Method 1008

BDL = Below Detection Limit of Analytical Method. (Detection levels in ppm are a function of sample volume; therefore, detection levels for each influent and effluent sample vary.

Detection levels for each influent and effluent air sample are specified in analytical reports included in Atlantic's^R monthly reports on file at the AFCEE/MMR IRP offices at Otis ANGB).

¹ Low Destruction Efficiency Corresponds with System Operational Changes (off-gas treatment system carbon change-out).

TAB E 8.3
SUMMARY OF SVE WELL VOC CONCENTRATIONS (from Extracted Vapor)
November 1995 through February 1998
FS-12 Product Recovery System
Massachusetts Military Reservation

Date	Active (A) Static (S)	SVE Well No.																			SVE Well No.				Average
		SV-1	SV-2	SV-3	SV-4	SV-5	SV-6	SV-7	SV-8	SV-9	SV-10	SV-11	SV-12	SV-13	SV-14	SV-15	SV-16	SV-17	SV-18	SV-19	SV-20	SV-21	SV-23	SV-24	
11/1/95	A	62.0	62.0	62.0	145.0	104.0	104.0	83.0	104.0	124.0	124.0	83.0	62.0	124.0	124.0	62.0	20.0	104.0	104.0	41.0	41.0	41.0	NA	NA	84.8
12/21/95	A	52.0	43.0	35.0	280.0	36.0	216.0	5.0	169.0	130.0	49.0	100.0	142.0	223.0	203.0	53.0	3.4	178.0	147.0	0.3	76.0	67.0	NA	NA	105.1
1/31/96	S	23.0	79.0	76.0	195.0	126.0	121.0	42.0	154.0	68.0	100.0	38.0	84.0	50.0	118.0	36.0	13.0	89.0	92.0	18.5	55.0	7.4	NA	NA	75.5
2/16/96	A	1.0	5.2	10.2	48.0	50.0	32.0	14.0	35.0	30.0	36.0	15.0	18.2	BDL	30.0	BDL	BDL	BDL	0.0	BDL	BDL	BDL	NA	NA	25.0
4/9/96	S	11.0	14.0	4.9	390.0	32.0	52.0	26.0	19.0	24.0	30.0	4.2	8.8	9.0	90.0	4.8	6.0	13.2	15.8	30.0	42.0	38.0	NA	NA	41.2
5/17/96	S	3.0	5.0	6.0	17.0	14.0	9.0	3.0	12.0	7.0	9.5	3.0	2.0	3.0	2.5	3.0	1.0	1.5	2.0	2.0	4.0	4.0	NA	NA	5.4
5/28/96	A	1.0	BDL	4.2	7.4	11.6	8.4	2.4	6.0	9.0	8.6	2.0	5.0	8.8	10.2	6.0	BDL	7.6	10.0	7.0	3.5	11.0	NA	NA	6.8
8/6/96	S	1.4	1.7	2.1	3.2	11.4	26.0	8.4	58.0	12.6	9.7	5.4	2.8	13.4	3.0	2.6	2.4	3.0	6.6	2.4	1.6	2.0	NA	NA	8.6
9/6/96	A	0.4	0.4	1.4	6.4	16.8	8.8	3.3	8.4	10.8	5.8	3.6	2.8	24.0	22.0	4.4	1.8	12.0	24.0	1.4	2.5	2.2	NA	NA	7.8
11/12/96	S	0.5	0.5	0.5	0.5	1.0	0.5	0.5	2.0	0.5	1.2	0.8	0.4	1.0	2.2	0.7	0.6	0.6	0.0	0.5	3.8	3.8	0.6	NA	0.9
11/19/96	A	0.2	0.1	0.7	3.4	7.2	2.2	3.0	4.5	4.6	1.8	2.6	2.6	26.0	17.2	4.4	1.8	6.9	18.2	3.8	1.9	3.0	NA	NA	5.5
2/7/97	S	0.1	0.1	0.2	5.8	0.2	0.9	0.5	1.6	0.4	4.5	1.1	0.3	2.1	0.2	0.3	0.2	0.2	0.2	0.2	0.2	0.1	NA	NA	0.9
2/20/97	A	6.2	4.2	3.4	1.7	4.0	3.9	4.8	4.4	3.8	5.7	5.2	5.3	7.2	12.3	5.2	4.5	4.5	6.0	5.1	4.2	3.8	NA	NA	5.0
4/14/97	S	BDL	BDL	BDL	0.8	BDL	BDL	BDL	BDL	BDL	0.6	BDL	BDL	BDL	1.2	BDL	BDL	BDL	BDL	BDL	BDL	BDL	NA	NA	0.9
5/22/97	A	0.2	BDL	0.2	0.6	0.2	0.8	0.8	0.4	0.2	0.2	0.5	BDL	1.2	11.6	2.0	0.6	0.6	1.0	0.7	0.2	0.2	NA	NA	1.2
7/7/97	S	0.8	1.0	2.8	40.0	0.2	0.3	0.8	BDL	BDL	6.0	*DA	0.4	0.4	0.5	0.3	0.4	0.4	0.4	0.2	0.2	0.4	NA	NA	3.1
7/15/97	A	1.0	0.6	0.5	0.8	0.4	0.2	0.5	0.4	0.4	0.3	0.7	0.4	0.4	8.6	1.0	1.0	0.8	0.5	0.4	0.8	1.0	NA	NA	1.0
8/29/97	S	0.5	0.1	1.1	1.5	0.4	0.1	0.1	2.3	0.8	0.2	0.2	0.1	0.2	0.3	0.2	0.2	0.1	0.3	0.2	0.2	0.1	NA	NA	0.4
9/12/97	A	1.2	0.4	0.8	0.6	0.6	0.6	1.0	1.0	0.8	1.0	1.2	0.7	1.0	1.2	1.0	1.0	1.2	1.4	1.2	1.0	0.8	NA	NA	0.9
11/17/97	A	0.0	0.1	0.2	3.8	0.2	0.1	0.5	10.2	0.1	0.4	0.4	0.2	0.1	11.6	1.0	0.2	2.0	1.5	0.6	NA	NA	0.3	3.0	1.7
12/12/97	S	0.4	0.3	0.4	3.6	2.8	3.2	0.4	33.5	2.5	0.2	1.3	1.2	2.4	1.4	1.2	1.8	8.0	2.0	0.2	NA	NA	0.4	0.4	3.5

Notes:
All readings are in ppm (parts per million)
*DA = Denied access jammed port
NA = Not Analyzed
BDL = Below Detection Limit

8.4 Evaluation of VOC Mass Removal Rates for SVE Wells Compared to Closure Criteria

One of the three closure criteria included in the Action Memorandum (*ASI 1996*) specifies the VOC removal rate for each SVE well must be less than 0.5 pounds per day over three consecutive sampling periods. Active VOC concentrations measured in each SVE well on 15 July 1997, 12 September 1997, and 17 November 1997 (Table 8.3) were used to determine VOC mass removal rates over three consecutive sampling periods. Table 8.4 calculates actual VOC mass removal rates for each SVE well during the three consecutive sampling periods. Mass removal rates in each of the 23 SVE wells were less than 0.5 pound per day over three consecutive sampling periods, except for wells SV-8 and SV-14. The maximum removal rate calculated for these two wells was 1.13 pounds per day, less than three times the closure criterion of 0.5 pound per day.

Based on these results, the recovery rate closure criteria of 0.5 pound per day over three consecutive sampling periods has been met except for SVE wells SV-8 and SV-14. The contaminant removal rate exceeded the closure criteria in SV-8 one time. The removal rate was 0.96 pounds per day, which exceeded the closure criteria by 0.46 pounds per day. The contaminant removal rate achieved in SV-14 exceeded closure criteria on two occasions. The rates were 0.75 pounds per day and 1.13 pounds per day, which exceed the closure criteria by 0.25 and 0.63 pounds per day respectively.

It was not considered practicable by AFCEE to continue operation of the extraction system to reduce contaminant levels in two individual wells. The system was not designed to allow extraction from just two wells, as the vacuum extraction system requires a minimum airflow rate. The two wells alone could not provide the necessary airflow at vacuum pressures that could be sustained by the wells. Operation of the entire system when only two wells slightly exceed removal rate criteria would result in excessive costs for a minimum result. The average removal rate per well during this period was approximately 0.08 pound/day, which is well below the closure criterion. This indicates the system was extremely effective at removing source area contamination capable of being removed under design conditions specified in the contract technical specifications (*ASI 1994*) and long term monitoring was recommended for residual contamination.

8.5 Soil Sampling Results Compared to Closure Criteria

Closure soil sampling in accordance with Appendix B of the Final Action Memorandum (*ASI 1996*) was implemented in February 1998 to confirm the absence of petroleum hydrocarbon and EDB in subsurface soils. Samples were collected from test borings shown in Figure 8.1. Ten soil borings were advanced and samples were collected at 5-foot intervals from 10 feet above the water table to ten feet below the water table. (Boring logs for soil borings SB-1 through SB-10 are included as Appendix I.) A total of four samples per boring were submitted for laboratory analysis for Volatile and Extractable Petroleum Hydrocarbons (VPH/EPH) and EDB. Average arithmetic averages were calculated from data collected at each soil boring to determine exposure point concentrations (310 CMR 40.0926) which were then compared to applicable MA DEP Method 1 S-3/GW-1 and Method 1 S-3/GW-3 standards. All exposure point concentrations for VPH and EPH were below applicable standards (310 CMR 40.0973). Hot spots (310 CMR 40.0006) were identified at borings SB-1 and SB-5. Individual sample results exceeded MA DEP Method 1 S-3/GW-1 and Method 1 S-3/GW-3 standards, but exposure point concentrations were below the standards. A summary of the analytical results is tabulated in Table 8.5 and the complete reference data is included as Appendix C.

Locations for soil boring SB-3, SB-5, and SB-7 (Figure 8.1) were chosen due to evidence of free product in wells WT-11, SV-4, SV-5, SV-8, SV-9, SV-12, and SV-13 during previous sampling activities. Soil borings SB-9 and SB-10 were chosen to represent the southwest extent of the source area and to verify that any remaining free product north of these locations had not migrated downgradient of the defined south-southeast boundary of the source area during operation of the remediation system. Soil borings SB-1, SB-4, and SB-6 were located near existing wells that had existing soil analytical data available. Available baseline soil data allowed placement of these borings in areas known to have initially exceeded MA DEP cleanup standards and allowed for a quantitative determination of the effectiveness of the remediation system. Soil borings SB-2 and SB-8 were chosen to verify the effectiveness of the remediation system along the estimated eastern and southern extent of the source area.

Based on these results, the closure criteria for subsurface soil have been met.

8.6 Groundwater Sampling Results Compared to Closure Criteria

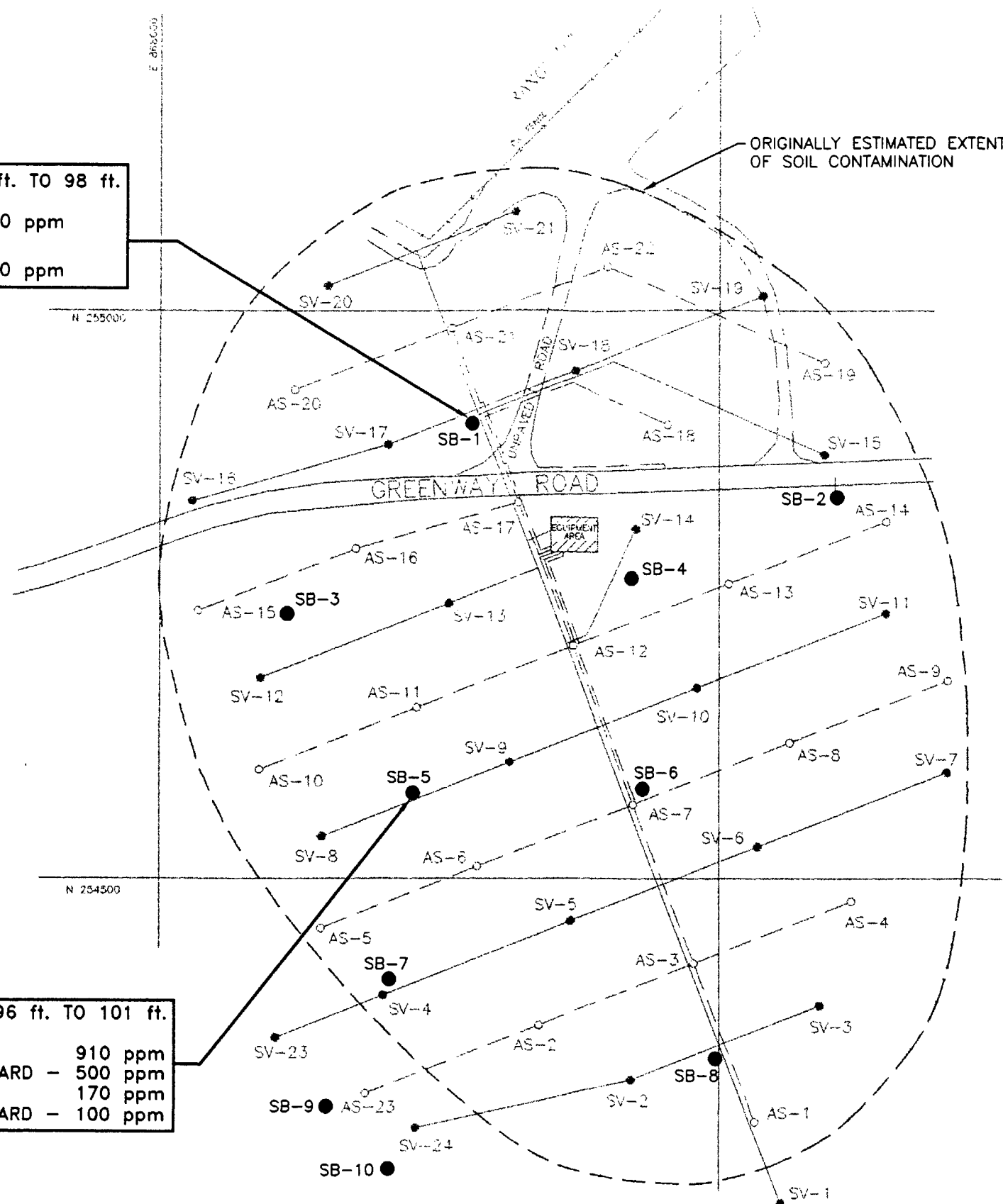
Baseline concentrations of BTEX and EDB in the source area groundwater were estimated for 5 selected groundwater-monitoring wells (OW-2, WT-6, WT-15, WT-18, and WT-20). Samples were collected on November 1, 1995 and analyzed by Barnstable County Department of Health and the Environment Water Quality Laboratory. In addition, during this sampling event, free product was detected in wells WT-11, WT-13, WT-17, and WT-19. Detailed analytical results are included in Atlantic®'s monthly report, dated October 23, 1995 through November 22, 1995. SVE wells SV-1, SV-4 and SV-11 were not sampled during the initial operational phase of the system as specified in Appendix B of the Final Action Memorandum (*ASI 1996*); however, these wells were sampled during subsequent sampling events.

Results of groundwater sampling events conducted during the operating life of the AS/SVE system, shown in Table 8.6, indicate that residual concentrations of BTEX and EDB above MA DEP cleanup standards exist in the FS-12 source area within the zone of saturation. Locations where groundwater exceeds MA DEP cleanup standards are shown in Figure 8.2. Groundwater sampling results, however, do indicate an overall reduction in BTEX and EDB concentrations in the source area.

Continued operation of the AS/SVE system was determined to be non-practicable. AFCEE's modeling analysis for the FS-12 groundwater plume showed that any dissolved contaminants emanating from the source area as a result of residual soil contamination would be captured and remediated by the existing downgradient extraction and treatment system. Long term monitoring was recommended to evaluate the residual source area groundwater contamination.

Based on these results, the removal action goals for groundwater have not been met.

SAMPLE COLLECTED FROM INTERVAL 96 ft. TO 98 ft.
BELOW GRADE (BELOW WATER TABLE)
VPH (C9-C10) CONC. - 240 ppm
MADEP METHOD 1
S-3/GW-1 (AROMATICS) STANDARD - 100 ppm



SAMPLE COLLECTED FROM INTERVAL 96 ft. TO 101 ft.
BELOW GRADE (BELOW WATER TABLE)
VPH (C5-C8 ALIPHATICS) - 910 ppm
MADEP METHOD 1 S-3/GW-1 STANDARD - 500 ppm
VPH (C9-C10 AROMATICS) - 170 ppm
MADEP METHOD 1 S-3/GW-1 STANDARD - 100 ppm

LEGEND

- AIR SPARGING WELL
- SOIL VENTING WELL
- AIR SPARGING PIPE
- SOIL VENTING PIPE
- SOIL BORING

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SCALE IN FEET
120 60 0 60 120

FIGURE 8.1
LOCATIONS OF SOIL BORINGS USED
TO VERIFY SITE CLOSURE
FS-12 Source Area Removal Action
Summary Report
Massachusetts Military Reservation

SCALE: 1"=120'
DATE: 3-1-00
DWN BY: KVP
FILENAME: FS12CR04.DWG

TABLE 8.4
VOC MASS REMOVAL RATES FOR SVE WELLS

Well No.	SV-1			SV-2			SV-3		
Date	7/15/97	9/12/97	11/17/97	7/15/97	9/12/97	11/17/97	7/15/97	9/12/97	11/17/97
VOC Concentration (ppm) ¹	1.0	1.2	0.0	0.6	0.4	0.1	0.5	0.8	0.2
Vacuum Pressure (inH ₂ O) ¹	3.5	3.5	3.6	4.8	4.8	4.2	4.0	4.0	2.4
Temperature (°F) ²	51.7	50.1	46.9	51.7	50.1	46.9	51.7	50.1	46.9
Flow Rate (acfm) ¹	165.0	165.0	175.0	148.0	148.0	148.0	139.0	139.0	148.0
Flow Rate (scfm) ³	168.8	169.3	180.7	150.9	151.4	152.6	142.0	142.5	153.3
Contaminants Removed (lbs/day) ⁴	0.06	0.07	0.00	0.03	0.02	0.01	0.02	0.04	0.01

Well No.	SV-4			SV-5			SV-6		
Date	7/15/97	9/12/97	11/17/97	7/15/97	9/12/97	11/17/97	7/15/97	9/12/97	11/17/97
VOC Concentration (ppm) ¹	0.8	0.6	3.8	0.4	0.6	0.2	0.2	0.6	0.1
Vacuum Pressure (inH ₂ O) ¹	4.0	4.0	4.1	5.5	5.5	5.8	6.5	6.5	5.2
Temperature (°F) ²	51.7	50.1	46.9	51.7	50.1	46.9	51.7	50.1	46.9
Flow Rate (acfm) ¹	157.0	157.0	144.0	209.0	209.0	214.0	218.0	218.0	161.0
Flow Rate (scfm) ³	160.4	160.9	148.5	212.8	213.4	219.7	221.4	222.1	165.6
Contaminants Removed (lbs/day) ⁴	0.04	0.03	0.20	0.03	0.04	0.02	0.02	0.05	0.01

Well No.	SV-7			SV-8			SV-9		
Date	7/15/97	9/12/97	11/17/97	7/15/97	9/12/97	11/17/97	7/15/97	9/12/97	11/17/97
VOC Concentration (ppm) ¹	0.5	1.0	0.5	0.4	1.0	10.2	0.4	0.8	0.1
Vacuum Pressure (inH ₂ O) ¹	3.5	3.5	4.5	4.3	4.3	5.6	6.5	6.5	6.5
Temperature (°F) ²	51.7	50.1	46.9	51.7	50.1	46.9	51.7	50.1	46.9
Flow Rate (acfm) ¹	139.0	139.0	148.0	183.0	183.0	262.0	235.0	235.0	200.0
Flow Rate (scfm) ³	142.2	142.6	152.5	186.9	187.4	269.2	238.6	239.4	205.0
Contaminants Removed (lbs/day) ⁴	0.02	0.05	0.03	0.03	0.07	0.96	0.03	0.07	0.01

TABLE 8.4
VOC MASS REMOVAL RATES FOR SVE WELLS

2 of 4

Well No.	SV-10			SV-11			SV-12		
Date	7/15/97	9/12/97	11/17/97	7/15/97	9/12/97	11/17/97	7/15/97	9/12/97	11/17/97
VOC Concentration (ppm) ¹	0.3	1.0	0.4	0.7	1.2	0.4	0.4	0.7	0.2
Vacuum Pressure (inH ₂ O) ¹	7.5	7.5	7.4	3.0	3.0	2.3	6.0	6.0	3.2
Temperature (°F) ²	51.7	50.1	46.9	51.7	50.1	46.9	51.7	50.1	46.9
Flow Rate (acfm) ¹	244.0	244.0	135.0	113.0	113.0	109.0	244.0	244.0	148.0
Flow Rate (scfm) ³	247.2	247.9	138.1	115.7	116.1	112.9	248.1	248.8	152.9
Contaminants Removed (lbs/day) ⁴	0.03	0.09	0.02	0.03	0.05	0.02	0.03	0.06	0.01

Well No.	SV-13			SV-14			SV-15		
Date	7/15/97	9/12/97	11/17/97	7/15/97	9/12/97	11/17/97	7/15/97	9/12/97	11/17/97
VOC Concentration (ppm) ¹	0.4	1.0	0.1	8.6	1.2	11.6	1.0	1.0	1.0
Vacuum Pressure (inH ₂ O) ¹	4.5	4.5	4.7	6.3	6.3	6.8	3.5	3.5	2.2
Temperature (°F) ²	51.7	50.1	46.9	51.7	50.1	46.9	51.7	50.1	46.9
Flow Rate (acfm) ¹	165.0	165.0	161.0	244.0	244.0	271.0	152.0	152.0	96.0
Flow Rate (scfm) ³	168.4	168.9	165.8	247.9	248.7	277.6	155.5	156.0	99.5
Contaminants Removed (lbs/day) ⁴	0.02	0.06	0.01	0.75	0.10	1.13	0.05	0.05	0.03

Well No.	SV-16			SV-17			SV-18		
Date	7/15/97	9/12/97	11/17/97	7/15/97	9/12/97	11/17/97	7/15/97	9/12/97	11/17/97
VOC Concentration (ppm) ¹	1.0	1.0	0.2	0.8	1.2	2.0	0.5	1.4	1.5
Vacuum Pressure (inH ₂ O) ¹	4.3	4.3	0.8	4.0	4.0	0.9	4.0	4.0	1.1
Temperature (°F) ²	51.7	50.1	46.9	51.7	50.1	46.9	51.7	50.1	46.9
Flow Rate (acfm) ¹	226.0	226.0	58.0	191.0	191.0	64.0	218.0	218.0	57.0
Flow Rate (scfm) ³	230.8	231.5	60.3	195.2	195.8	66.5	222.7	223.4	59.2
Contaminants Removed (lbs/day) ⁴	0.08	0.08	0.00	0.05	0.08	0.05	0.04	0.11	0.03

TABLE 8.4
VOC MASS REMOVAL RATES FOR SVE WELLS

3 of 4

Well No.	SV-19			SV-20			SV-21		
Date	7/15/97	9/12/97	11/17/97	7/15/97	9/12/97	11/17/97	7/15/97	9/12/97	11/17/97
VOC Concentration (ppm) ¹	0.4	1.2	0.6	0.8	1.0	NA	1.0	0.8	NA
Vacuum Pressure (inH ₂ O) ¹	4.0	4.0	0.8	3.5	3.5	NA	4.5	4.5	NA
Temperature (°F) ²	51.7	50.1	46.9	51.7	50.1	NA	51.7	50.1	NA
Flow Rate (acfm) ¹	183.0	183.0	48.0	183.0	183.0	NA	191.0	191.0	NA
Flow Rate (scfm) ³	187.0	187.6	49.9	187.2	187.8	NA	194.9	195.5	NA
Contaminants Removed (lbs/day) ⁴	0.03	0.08	0.01	0.05	0.07	NA	0.07	0.05	NA

Well No.	SV-23			SV-24		
Date	7/15/97	9/12/97	11/17/97	7/15/97	9/12/97	11/17/97
VOC Concentration (ppm) ¹	NA	NA	0.3	NA	NA	3.0
Vacuum Pressure (inH ₂ O) ¹	NA	NA	2.1	NA	NA	4.2
Temperature (°F) ²	NA	NA	46.9	NA	NA	46.9
Flow Rate (acfm) ¹	NA	NA	87.0	NA	NA	96.0
Flow Rate (scfm) ³	NA	NA	90.2	NA	NA	99.0
Contaminants Removed (lbs/day) ⁴	NA	NA	0.01	NA	NA	0.10

TABLE 8.4
VOC MASS REMOVAL RATES FOR SVE WELLS

NOTES:

¹ VOC concentration, pressure, and flow rates associated with 7/12/97 and 9/12/97 data were measured during week of 6/10-14/96 prior to shut down of wells SV-20 and 21. VOC concentration, pressure, and flow rates associated with 11/17/97 data were measured on 11/24/97 subsequent to shutdown of wells SV-20 and 21.

² Temperatures reflect the daily average for the associated month.

³ Conversion from actual to standard flow rate relative to standard absolute temperature (528°R) and pressure (407.5 inH₂O) using the following equation: $(acfm) \times ((P_{atm} + P_{gauge}) / P_{std}) \times ((T_{std} + 460) / (T_{act} + 460))$

where:

- acfm = actual flow rate (ft³/min)
- P_{atm} = std atmospheric pressure (407.5 inH₂O)
- P_{gauge} = measured vacuum pressure (-inH₂O)
- P_{std} = std absolute pressure (407.5 inH₂O)
- T_{std} = std temperature (68 °F)
- T_{act} = measured system temperature (°F)

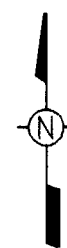
⁴ Contaminant removal rate calculated using the following equation and associated assumptions:
 $(conc) \times (MW / .0241) \times (1 \times 10^{-6}) \times (2.2 \times 10^{-3}) \times (.028) \times (scfm) \times (1440)$

where:

- conc = measured concentration of VOCs (ppm)
- MW = average molecular weight of VOCs (95 g/mole)
- 0.0241 = conversion factor to ug/m³
- 1x10⁻⁶ = conversion (g/ug)
- 2.2x10⁻³ = conversion (lb/g)
- 0.028 = conversion (m³/ft³)
- scfm = standardized flow rate (ft³/min)
- 1440 = conversion (min/day)

Assumptions:

- VOC concentration consists of 100% BTEX distributed in equal parts (25% of each constituent).
- Affect of moisture content on dry gas flow rate is negligible in conversion from actual to standard flow rate.
- Average molecular weight (MW) of BTEX (95 g/mole) is representative of MW of VOCs in air stream.
- Actual system flow rates were converted to standard temperature and pressure flow rates for purposes of consistency with conversion factors in calculating daily mass removal rates. The average difference between actual and standard flow rates is approximately 4%; therefore, the resulting effect on the calculated mass removal rate is considered negligible for purposes of this report.



ORIGINALLY ESTIMATED EXTENT OF SOIL CONTAMINATION

SV-13

DATE	BENZENE	TOLUENE	ETHYL-BENZENE	TOTAL XYLENES	EDB
3/17/98	68	1600	-	-	3.9
MADEP METHOD 1 GW-1 STANDARDS	5	1,000	700	10,000	0.02

SV-4

DATE	BENZENE	TOLUENE	ETHYL-BENZENE	TOTAL XYLENES	EDB
11/15/96	-	1600	-	-	9
7/8/97	-	6700	-	-	2
12/16/97	20	4500	-	-	6.1
3/17/98	32	2700	-	-	5.9
MADEP METHOD 1 GW-1 STANDARDS	5	1,000	700	10,000	0.02

GMW-100

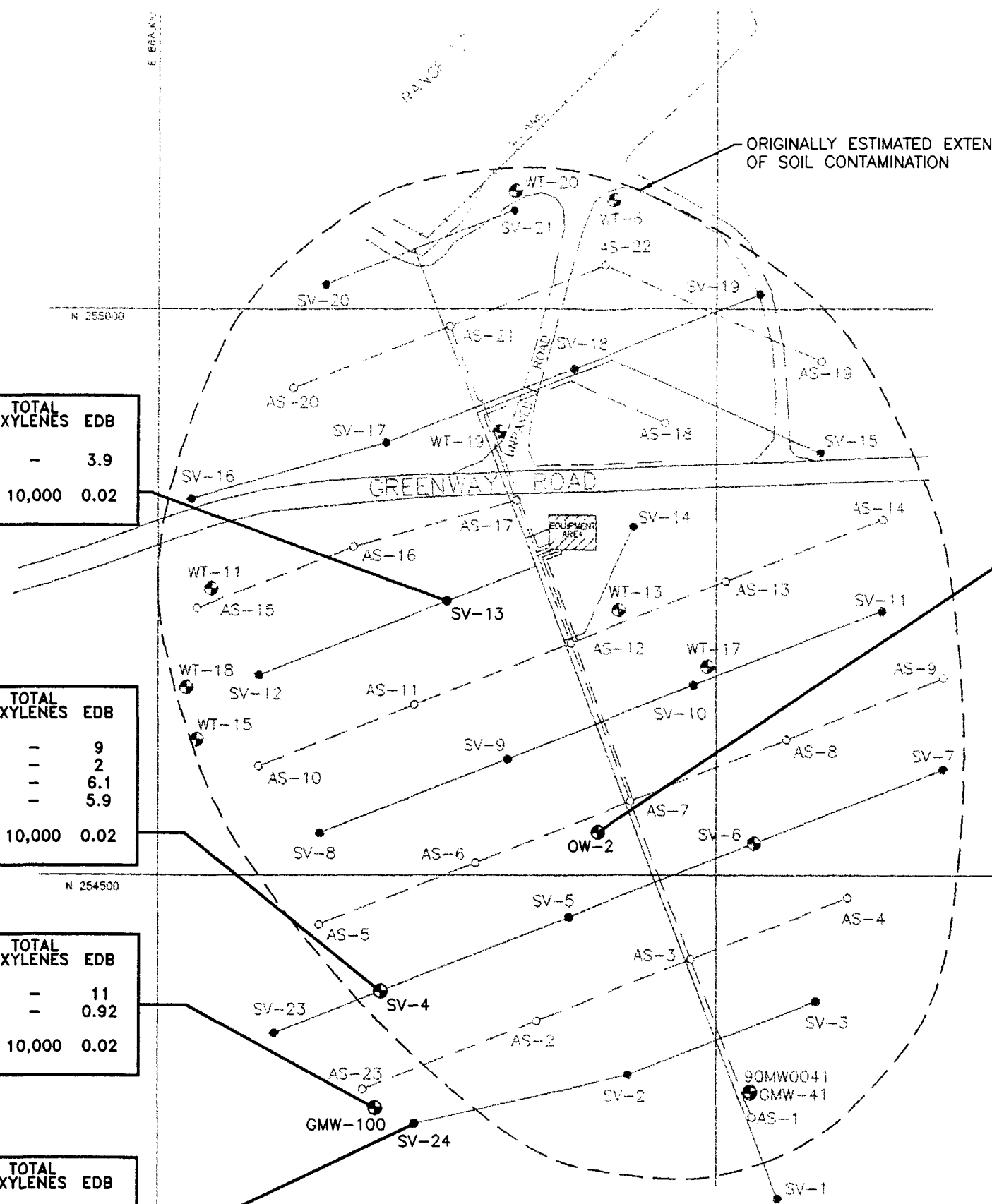
DATE	BENZENE	TOLUENE	ETHYL-BENZENE	TOTAL XYLENES	EDB
7/8/97	330	2300	-	-	11
12/16/97	-	-	-	-	0.92
MADEP METHOD 1 GW-1 STANDARDS	5	1,000	700	10,000	0.02

SV-24

DATE	BENZENE	TOLUENE	ETHYL-BENZENE	TOTAL XYLENES	EDB
12/16/97	-	-	-	-	1.1
3/17/98	7	-	-	-	0.32
MADEP METHOD 1 GW-1 STANDARDS	5	1,000	700	10,000	0.02

OW-2

DATE	BENZENE	TOLUENE	ETHYL-BENZENE	TOTAL XYLENES	EDB
11/1/95	-	6400	2800	-	-
MADEP GW-1 CLEANUP STANDARDS	5	1,000	700	10,000	0.02



NOTE: ALL CONCENTRATIONS ARE IN PARTS PER BILLION (ppb)

- LEGEND**
- AIR SPARGING WELL
 - SOIL VENTING WELL
 - AIR SPARGING PIPE
 - SOIL VENTING PIPE
 - MONITORING WELL

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SCALE IN FEET

FIGURE 8.2
LOCATIONS OF GROUNDWATER
SAMPLES USED TO VERIFY
SITE CLOSURE
FS-12 Source Area Removal Action
Summary Report
Massachusetts Military Reservation

SCALE: 1"=120' DWN BY: KVP
DATE: 03-01-00 FILENAME: FS12CR07.DWG

TABLE 8.5

**Average VPH and EPH Concentrations at each Closure Spill Boring Location
(SB-1 through SB-10)**

Soil Boring Locations	VPH (ppm)			EPH (ppm)		
	C5 - C8	C9 - C12	C9 - C10	C9 - C18	C19 - C36	C11 - C22
SB-1	78.86	43.82	61.79	547.50	26.75	65.75
SB-2	0.35	0.34	0.18	15.00	15.00	15.00
SB-3	0.65	0.26	0.13	15.00	11.26	15.00
SB-4	0.17	0.29	0.13	15.00	15.00	15.00
SB-5	325.33	61.03	62.13	3.90	15.00	15.00
SB-6	10.85	4.14	2.75	11.32	15.00	11.26
SB-7	10.46	8.07	3.49	7.53	15.00	15.00
SB-8	0.24	0.13	0.13	15.00	15.00	15.00
SB-9	0.13	0.13	0.13	15.00	15.00	15.00
SB-10	0.13	0.13	0.13	15.00	15.00	15.00
Average Exposure Point Concentration	42.72	11.83	13.1	66.03	15.80	19.70
Method 1 S3/GW-1 Cleanup Standard	500.00	5000.00	100.00	5000.00	5000.00	200.00

Note: Average concentrations based on results of four sample locations per boring (Appendix C). One half of the reporting limit (VPH = 0.26 ppm, EPH = 30 ppm) was used to represent BRL results for averaging purposes.

TABLE 8.6
SUMMARY OF GROUNDWATER SAMPLING

1 of 2

FS-12 Product Recovery System
Massachusetts Military Reservation

WELL #	DATE	TIME	NAPL	BENZENE	TOLUENE	ETHYLBENZENE	TOTAL XYLENES	EDB
SV-1	11/1/95	14:40	0	NT	NT	NT	NT	NT
	11/15/96	13:11	Sheen	BDL	BDL	BDL	BDL	BDL
	7/8/97	11:45	0	BDL	1	BDL	BDL	BDL
	12/16/97	13:45	0	BDL	BDL	BDL	BDL	BDL
SV-4	11/1/95	14:40	0	NT	NT	NT	NT	NT
	11/15/96	13:11	Sheen	29	1600 *	170	740	9 *
	7/8/97	14:15	0	BDL	6700 *	320	1,240	2 *
	12/16/97	14:00	0	20 *	4500 *	170	690	6.1 *
	3/17/98	12:45	0	32 *	2700 *	160	610	5.9 *
SV-8	12/16/97	14:11	0	0.6	48	4	36	0.02
	3/17/98	13:30	0	BDL	17	7	56	BDL
SV-11	11/1/95	14:40	0	NT	NT	NT	NT	NT
	11/15/96	13:11	Sheen	BDL	1	3	11	BDL
SV-13	3/17/98	14:30	0	68 *	1600 *	280	1620	3.9 *
SV-14	12/16/97	14:40	0	1	36	4	21	0.02
	3/17/98	15:00	0	BDL	16	10	49	BDL
SV-23	7/8/97	16:24	0	3	7	39	9	BDL
	12/16/97	15:05	0	BDL	3	1	2.6	BDL
SV-24	7/8/97	16:57	0	BDL	6	2	6	BDL
	12/16/97	15:32	0	BDL	5	0.8	3	1.1 *
	3/17/98	11:45	0	7 *	10	9.6	249	0.32 *
WT-6	11/1/95	14:40	0	BDL	BDL	BDL	BDL	BDL
	11/15/96	13:11	0	BDL	BDL	BDL	BDL	BDL
	12/16/97	14:50	0	BDL	13	0.9	4	0.006
WT-11	11/1/95	14:40	0.28	NT	NT	NT	NT	NT
	11/15/96	13:11	0	1	66	51	184	BDL
	7/8/97	15:27	0	2	39	65	210	BDL
	12/16/97	15:15	0	3	10	27	92	BDL

TABLE 8.6
SUMMARY OF GROUNDWATER SAMPLING

FS-12 Product Recovery System
Massachusetts Military Reservation

WELL #	DATE	TIME	NAPL	BENZENE	TOLUENE	ETHYLBENZENE	TOTAL XYLENES	EDB
WT-13	11/1/95	14:40	1.54	NT	NT	NT	NT	NT
	11/15/96	13:11	0	BDL	400	120	710	BDL
WT-15	11/1/95	14:40	0	BDL	760	60	350	BDL
	11/15/96	13:11	0	BDL	BDL	BDL	1	BDL
WT-17	11/1/95	14:40	1.24	NT	NT	NT	NT	NT
	11/15/96	13:11	0	BDL	53	27	110	BDL
WT-18	11/1/95	14:40	Sheen	BDL	1700 *	1400 *	600	BDL
	11/15/96	13:11	0	4	270	120	420	BDL
	7/8/97	15:50	0	2	22	29	104	BDL
	12/16/97	15:10	0	BDL	BDL	BDL	BDL	BDL
WT-19	11/1/95	14:40	0.16	NT	NT	NT	NT	NT
	11/15/96	13:11	0.09	NT	NT	NT	NT	NT
	3/17/98	15:30	0	5	5	3	109	BDL
WT-20	11/1/95	14:40	0	BDL	820	680	450	BDL
	11/15/96	13:11	0	BDL	BDL	BDL	BDL	BDL
OW-2	11/1/95	14:40	0	BDL	6400 *	2800 *	1900	1.19 *
	11/15/96	13:11	0	1	6	19	123	BDL
GMW-41	7/8/97	13:25	0	BDL	BDL	BDL	BDL	BDL
	12/16/97	16:00	0	BDL	BDL	BDL	BDL	BDL
GMW-100	8/7/97	12:13	0	330 *	2300 *	390	1,160	11 *
	12/16/97	15:48	0	BDL	5	0.7	3	0.92 *
Method 1 GW-1 Cleanup Standards				5	1,000	700	10,000	0.02
Lab Detection Limits				1	1	1	1	0.01

Notes:

* denotes contamination level in excess of MADEP Method 1 GW-1 Cleanup Standards

All values reported in micrograms per liter (ug/l) = parts per billion (ppb)

BDL = Below Detection Limit

NAPL = Non-Aqueous Phase Liquid (listed in feet)

EDB = Ethylene Dibromide

NT = Not Tested

9. CONCLUSION

Table 9.1 summarizes the system closure criteria specified in the Final Action Memorandum (*ASI 1996*) compared to the actual system performance achieved during the operational phase of the project.

Table 9.1
System Closure Criteria Compared to Actual System Performance

<i>Closure criteria specified in Appendix B of the Final Action Memorandum (ASI 1996)</i>	<i>Actual System Performance</i>
VOC removal rate per SVE well less than 0.5 pounds per day over 3 consecutive sampling periods.	Criteria satisfied for all SVE wells except SV-8 and SV-14. Average VOC removal rate for all SVE wells was 0.08 pounds per day, much less than the 0.5 pound per day criteria.
Contaminant concentrations in vadose zone soil less than MA DEP Method 1 S-3/GW-1 and Method 1 S-3/GW-3 standards specified in 310 CMR 40.0933.	All samples collected above the water table were below applicable MA DEP cleanup standards. Two of the 20 samples collected below the water table contained VPH and EPH contaminants above the applicable MA DEP cleanup standards; however, the average exposure concentration of the contaminants were below applicable MA DEP cleanup standards. Based on these results, the removal action goals for soil have been met.
Contaminant concentrations in groundwater less than MA DEP Method 1 GW-1 and Method 1 GW-3 standards specified in 310 CMR 40.0932.	19 source area wells sampled as part of closure requirements. Analytical results indicate samples collected from wells were below Method 1 GW-1 and Method 1 GW-3 standards, except for samples collected from SV-4 and SV-13, SV-24, OW-2, WT-18, and GMW-100.

In a March 1, 1999 letter from USEPA to AFCEE, regarding FS-12 source area closure, (Appendix A), the USEPA and MA DEP agreed that elevated levels in the zone of saturation would not be effectively addressed by continued operation of the AS/SVE system. As a condition to shutdown of the AS/SVE removal action at the FS-12 source area, AFCEE agreed to monitor ten (10) selected groundwater-monitoring wells on a semi-annual basis (Appendix A). During initial sampling of these 10 wells, three of the wells [90MW0051, ITW-01(8), and LWA-04] were unable to be sampled; therefore, a decision was made, with concurrence from the regulators, to eliminate these wells from the FS-12 performance monitoring evaluation (PME) program and to add well SV-6. These eight (8) wells were added to the FS-12 PME program commencing with the April/May 1999 sampling round, and the results are included in the applicable quarterly reports submitted to USEPA and MA DEP.

Based on results of groundwater (Appendix B) and soil (Appendix C) closure sampling, as well as the decreased mass removal rates determined in each SVE well towards the end of the operational phase of the AS/SVE system, the scope of work as specified in the Action Memorandum (*ASI 1996*) has been completed to the extent practicable with the condition that post-closure groundwater sampling be conducted as part of the FS-12 PME.

10. REFERENCES

- (ASI 1994) Advanced Sciences, Inc., "Final Design Package for the FS-12 Product Recovery System"; Volume I, Specifications (includes plans by reference); Volume II, Design Calculations; Volume III, Report of Air Sparging, Soil Vapor Extractions, and Product Recovery Pilot Studies Conducted at the FS-12 Source Area August 23, 1993 - October 1, 1993"; Installation Restoration Program, Massachusetts Military Reservation; Prepared for HAZWRAP; Oak Ridge, TN, July 1994.
- (ASI 1995) Advanced Sciences, Inc., "Remedial Investigation Report, FS-12 Study Area, Final"; Installation Restoration Program, Massachusetts Military Reservation; Prepared for HAZWRAP; Oak Ridge, TN, January 1995.
- (ASI 1996) Advanced Sciences, Inc., "Final Action Memorandum, AOC FS-12 Source Removal"; Prepared for AFCEE/MMR and Submitted by HAZWRAP; Oak Ridge, TN, November 1996.
- (NGB 1993) Letter dated June 28, 1993 from Daniel W. Santos to Mr. Paul Marchessault, Subject: Removal Action - AOC FS-12; June 1993.

APPENDIX A

- Letter from Jim Snyder, AFCEE, to Paul Marchessault, EPA Region I, dated November 9, 1998.
- Letter from Paul Marchessault, EPA Region I, to Jim Snyder, AFCEE, Subject: FS-12 Source Area Closure, dated March 1, 1999



DEPARTMENT OF THE AIR FORCE
HEADQUARTERS AIR FORCE CENTER FOR ENVIRONMENTAL EXCELLENCE
INSTALLATION RESTORATION PROGRAM
OTIS AIR NATIONAL GUARD BASE, MA 02542-5028

November 9, 1998

HQ AFCEE
322 E. Inner Road
Otis ANG Base, MA 02542

Mr. Paul Marchessault
USEPA-HAN/CANI
One Congress Street
Boston, MA. 02203-0001

Dear Mr. Marchessault:

The purpose of this letter is to document the shutdown of the Air Sparging and Soil Vapor Extraction System (AS/SVE) and site closure of the FS-12 source area. The AS/SVE system commenced operation on October 23, 1995, and was shut down on February 25, 1998. The shutdown was done as a prelude to confirmation sampling, and subsequent removal of the system components.

The confirmation sampling was conducted as agreed upon by the EPA and Massachusetts DEP, and involved soil borings at ten locations, with four soil samples taken at each location. Soil was collected in five foot intervals starting at ten feet above the water table and ending at ten feet below the water table. The samples were analyzed for Volatile and Extractable Petroleum Hydrocarbons (VPH/EPH), and 1,2-Dibromomethane. Only 2 of the 40 soil samples contained contaminants (VPH and EPH) at concentrations above applicable S-3/GW-1 soil cleanup standards (310 CMR 40.0975(6)(b)).

EPA and DEP representatives agreed that continued operation of the AS/SVE system would not be effective in removing the residual soil contaminants, and therefore the system was dismantled and removed in the spring/summer of 1998.

A Remedial Program Manager's (RPM) meeting was held on May 20, 1998, in response to a May 13, 1998, letter from DEP regarding the remaining dissolved EDB contaminants in groundwater at the site. AFCEE's modeling analysis of the groundwater plume showed that the groundwater contaminants at the source area would be remediated by the present groundwater extraction and treatment system. In order to confirm the modeling analysis, it was agreed to conduct further groundwater sampling by adding wells in the source area to the ongoing FS-12 ETR system PME sampling effort. This would help assess the fate and transport of the residual

groundwater contaminants at the source area, and provide rationale for future potential remedial actions. Ten wells were selected for EDB and VOC analysis and are identified in Attachment A. These wells will be sampled on a semiannual basis commencing in the first quarter of fiscal year 1999.

Therefore, with the addition of source area wells to the present PME program for the groundwater ETR, the FS-12 source area is considered closed for remedial action. AFCEE feels that the residual groundwater contaminants will be remediated by the presently operating ETR system, with on-going groundwater sampling to confirm progress.

If you have further questions or require additional information please contact Carter Fahy of my staff at (508) 968-4670, ext. 4675.

Sincerely



JIM F. SNYDER
Remediation Program Manager

Atch: Source Area PME Wells

Cc:

L. Pinaud, MA DEP

M. Minior, AFCEE/MMR

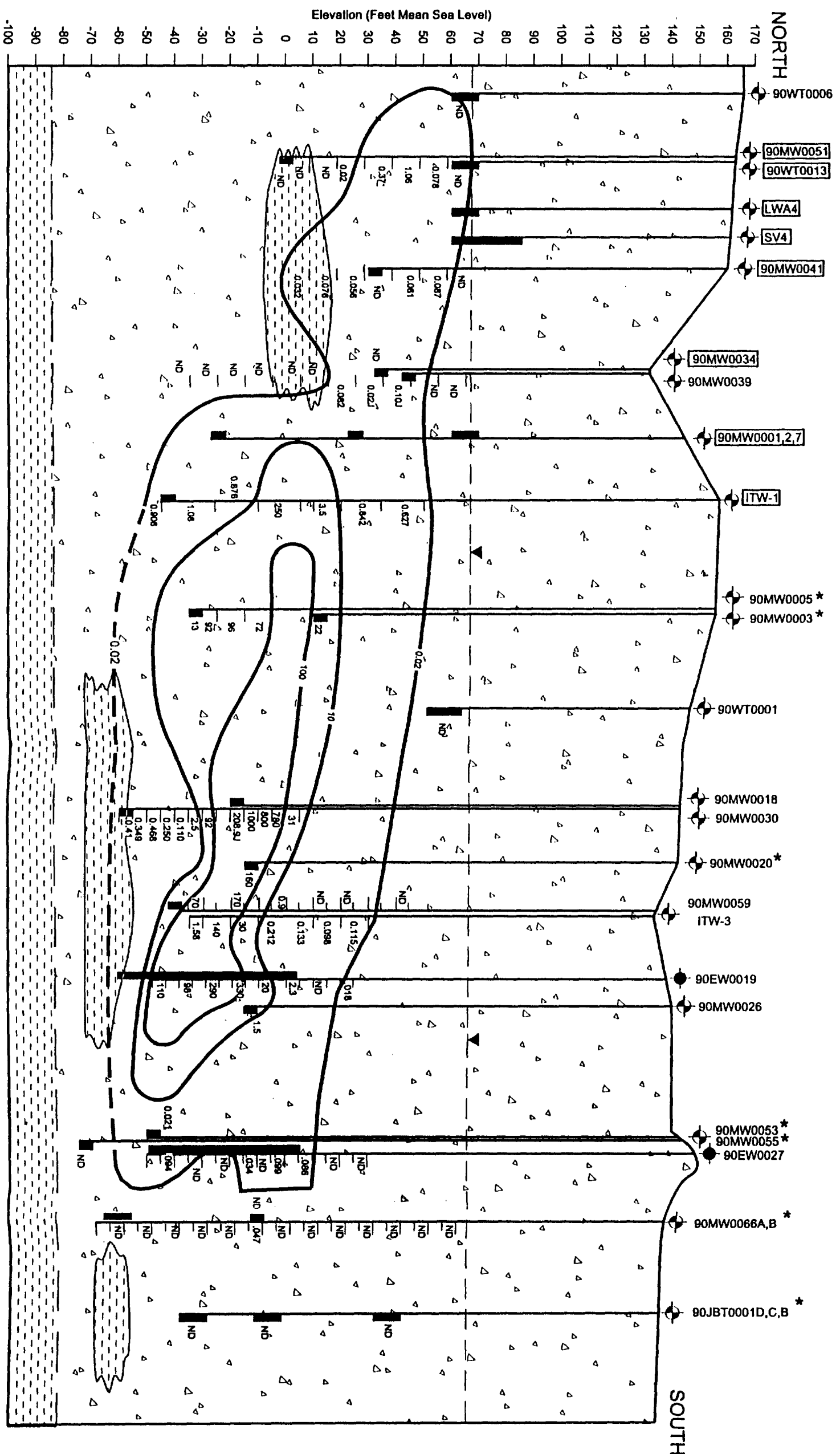
R. Davis, AFCEE/MMR ✓

D. Hill, ARNG (Bregman & Co.)

G. Petersen, JEG

B. Klein, JEG

Carter Fahy, Unitech

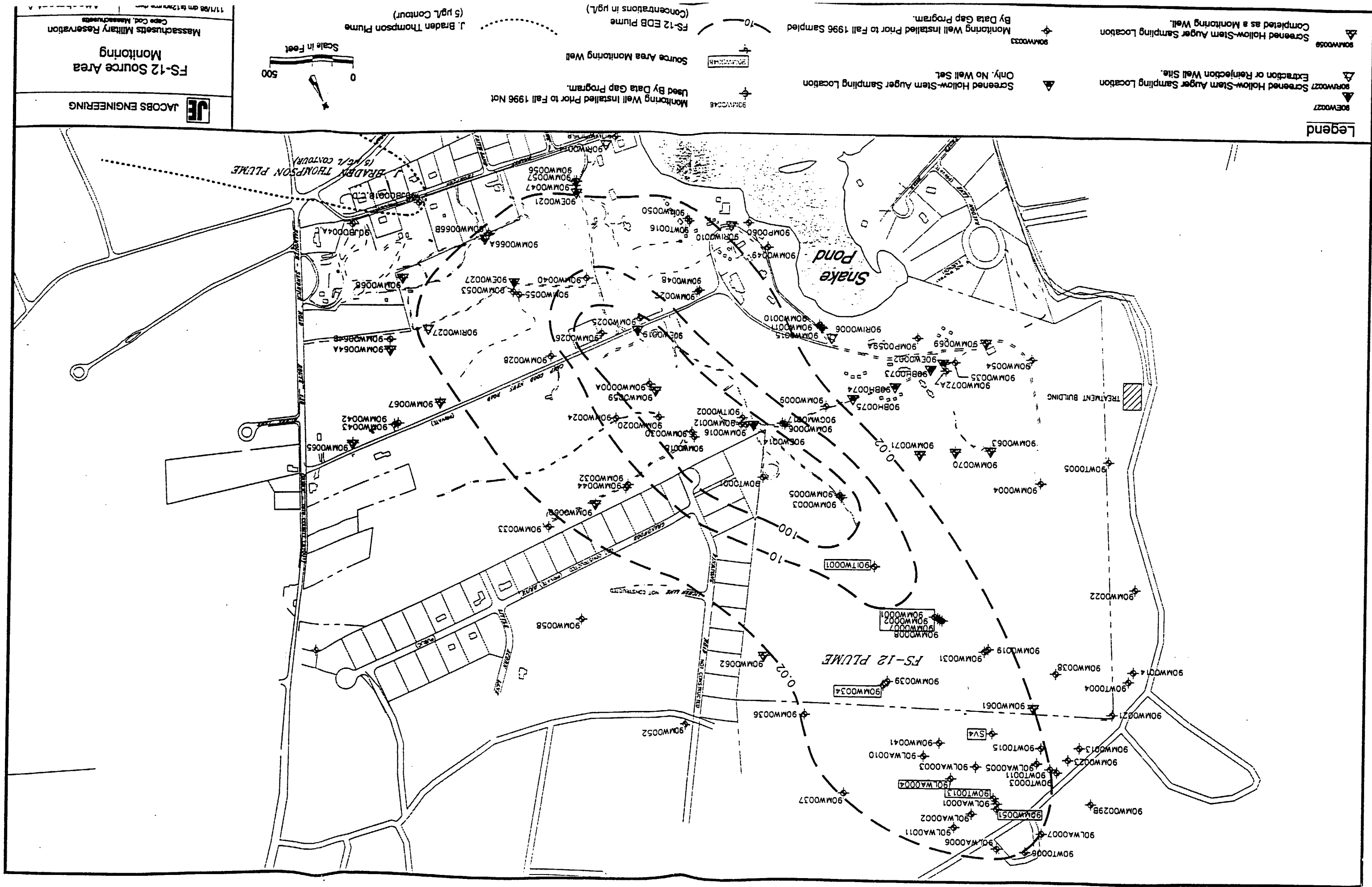


Legend

- Water Table
- Existing Monitoring Well
- Extraction Well
- Not Detected
- Monitoring Well
- Sample
- Estimated Value
- EDB Isoconcentration Contour Concentrations in µg/L
- Monitoring Well or Screened Hollow Stem Auger Sampled 1996
- Medium to Coarse Sand
- Silty Sand

JF JACOBS ENGINEERING

FS-12 Source Area Monitoring
Massachusetts Military Reservation
Cape Cod, Massachusetts
11/9/98 at Ft. A-125 Area



JE JACOBS ENGINEERING

ATTACHMENT A: FS-12 SOURCE AREA MONITORING

WELL ID	INVEST (1)	EASTING	NORTHING	SURF ELEV (FT MSL)	SCREEN LENGTH (FT)	TOS ELEV. (FT-MSL)	BOS ELV. (FT-MSL)	CENTER SCREEN ELEV (FT-MSL)	WELL DEPTH CLASS (2)
90MW0001	ESI	868193	253687	157.40	10.00	71.40	61.40	66.40	A
90MW0002	ESI	868186	253695	157.70	5.00	25.70	20.70	23.20	B
90MW0007	ESI	868181	253701	159.48	5.00	-21.80	-26.80	24.50	E
90MW0034	RI	868645	253868	131.10	5.00	37.40	32.50	34.95	B
90MW0041	RI	868529	254309	159.60	5.00	34.20	29.40	31.80	B
90MW0051	RI	868425	254799	162.00	5.00	1.90	-3.00	-0.55	D
ITW-01(8)	RI	868361	253252	157.70	1.00	-45.00	-44.00	-44.50	F
LWA-04	SOURCE	868570	254519	160.20	10.00	69.40	59.40	64.40	A
WT-13	RI	868411	254735	163.10	10.00	71.10	61.10	66.10	A
SV-4	SOURCE	868197	254398	158.70	30.00	89.20	59.20	74.20	A

NOTES: 1. Please reference the following studies

- a. ESI - Expanded Site Investigation performed by ASI under contract to HazWrap
- b. RI - 1995 Remedial Investigation by ASI under contract to HazWrap
- c. DATAGAP - Data Gap Investigation performed by Optech
- d. PRECONST - Preconstruction Investigation conducted by Jacobs under contract to AFCE
- e. SOURCE - Final Design package for the FS12 Product Recovery System conducted by ASI under contract to HazWrap.
- f. JBT - J. Braden Thompson Remedial Investigation prepared by Welren Engineers for MADEP

2. Well depth classes are defined for the following center of screen elevations:

- A. > 40 ft-msl
- B. > 20 and < 40 ft-msl
- C. > 0 and < 20 ft-msl
- D. > -20 and < 0 ft-msl
- E. > -40 and < -20 ft-msl
- F. > -60 and < -40 ft-msl
- G. < -60 ft-msl

TOS = top of screen
BOS = bottom of screen



UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 1
JOHN F. KENNEDY FEDERAL BUILDING
BOSTON, MASSACHUSETTS 02203-0001

6-1
R556
J6-

March 1, 1999

James F. Snyder
Remediation Program Manager
HQ AFCEE/MMR
322 East Inner Road
Otis ANG Base, MA 02542-5028



Re: FS-12 Source Area Closure

Dear Mr. Snyder:

This office is in receipt of your letter dated November 9, 1998, in which you document the site closure of the Air Sparging and Soil Vapor Extraction (AS/SVE) system at the FS-12 source area. Upon review of this information, and discussion with the MA DEP, this office agrees that AFCEE has completed the scope of work as delineated in the action memorandum, and approves the closure of the site.

However, as noted in your letter, there is residual EDB contamination in the groundwater, which has been agreed by all parties would not be addressed by continued operation of the AS/SVE system. Therefore, this office concurs with the ten (10) selected wells which AFCEE will monitor on a semi-annual basis. These wells must be added to the FS-12 performance monitoring evaluation (PME), and the results included in the quarterly reports submitted to this office. If the sampling results indicate continued ground water contamination in the source area, the need for expansion of the current extraction system must be considered.

If you have any questions, please do not hesitate to contact me at (617) 918-1388.

Sincerely,

Paul N. Marchessault, Remedial Project Manager
Office of Site Remediation and Restoration

cc: Mike Minor, AFCEE
Bob Davis, AFCEE
Len Pinaud, MA DEP
David Hill, Bregman & Company
Mike Jasinski, EPA
Brenda Haslett, EPA

**REVISIONS TO FS-12 SOURCE AREA MONITORING LOCATIONS
ASSOCIATED WITH THE PERFORMANCE MONITORING EVALUATION**

During PME sampling activities conducted during April/May 1999, it was determined that wells 90MW0051, LWA-04, and ITW-01(8) were unable to be sampled. It was decided shortly thereafter to add SV-6 as a post-closure monitoring location. The current wells included as part of the FS-12 PME include 90MW0001, 90MW0002; 90MW0007, 90MW0034, 90MW0041, WT-13, SV-4 and SV-6.

APPENDIX B

**Analytical Results for Source Area Groundwater Samples
Collected on March 17, 1998**

MMR/FS-12
Laboratory Results from March 17, 1998
BTEX Concentrations

SAMPLE #	DATE	BENZENE	TOLUENE	ETHY-BZNE	XYLENES
SVE-24	3/17/98	5	10	96	249
SVE-4	3/17/98	32	2700	160	610
SVE-8	3/17/98	BRL	17	7	56
SVE-13	3/17/98	68	1600	280	1620
SVE-14	3/17/98	BRL	16	10	49
WT-19	3/17/98	5	5	3	109

*DEP-GW-1

Cleanup Standards-

5

1000

700

10000

All analysis is measured in parts per billion (ppb)

Below Detection Limits - (BRL)

indicates levels in excess of DEP GW-1 Cleanup Standards

MMR/FS-12
Laboratory Results from March 17, 1998
EDB Concentrations

SAMPLE #	DATE	1,2-Dibromoethane (EDB)		
SVE-24	3/17/98		0.42	
SVE-4	3/17/98		1.50	
SVE-8	3/17/98		BRL	
SVE-13	3/17/98		1.50	
SVE-14	3/17/98		BRL	
WT-19	3/17/98		BRL	


*DEP-GW-1

Cleanup Standards-

0.02

All analysis is measured in parts per billion (ppb)

Below Detection Limits - (BRL)

 indicates levels in excess of DEP GW-1 Cleanup Standards

MMR/FS-12
Laboratory Results from March 17, 1998
Volatile Petroleum Hydrocarbon (VPH)
Extractable Petroleum Hydrocarbon (EPH)
Concentrations

SAMPLE #	DATE	VPH - Concentrations			EPH - Concentrations		
		C5-C8	C9-C12	C9-C10	C9 - C18	C19 - C36	C11 - C22
		Aliphatics	Aliphatics	Aromatics	Aliphatics	Aliphatics	Aromatics
SVE-24	3/17/98	550	BRL	550	BRL	BRL	BRL
SVE-4	3/17/98	2000	BRL	970	BRL	BRL	BRL
SVE-8	3/17/98	700	78	510	BRL	BRL	BRL
SVE-13	3/17/98	1600	BRL	2300	BRL	BRL	200
SVE-14	3/17/98	310	170	95	1100	BRL	210
WT-19	3/17/98	93	BRL	740	BRL	BRL	BRL

*DEP-GW-1

Cleanup Standards-	400	4000	200	4000	5000	200
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All analysis is measured in parts per billion (ppb)

Below Detection Limits - (BRL)

 indicates levels in excess of DEP GW-1 Cleanup Standards

GROUNDWATER ANALYTICAL

Groundwater Analytical, Inc.
228 Main Street
Buzzards Bay, MA 02532
Telephone (508) 759-4441
FAX (508) 759-4475

March 30, 1998

Mr. Gary Meyer
Atlantic Environmental
Technologies, Inc.
86 Faunce Corner Road
N. Dartmouth, MA 02747

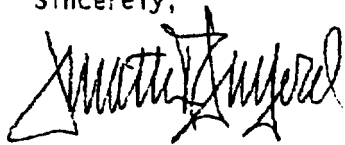
Dear Gary:

Enclosed are the EDB, Extractable Petroleum Hydrocarbons and Volatile Petroleum Hydrocarbons Analyses performed for the Otis FS-12 project, sampled on 03-17-98. This project was processed for Standard Two Week turnaround.

A brief description of the Quality Assurance/Quality Control procedures employed by Groundwater Analytical, and a statement of our state certifications are contained within the report. This letter authorizes the release of the analytical results and should be considered a part of this report.

Should you have any questions concerning this report, please do not hesitate to contact me.

Sincerely,



Jonathan R. Sanford
Vice President

JRS/awc
Enclosures

GROUNDWATER ANALYTICAL

EPA METHOD 504.1
EDB (GC/ECD)

Field ID: SV-24
Project: Otis FS-12
Client: Atlantic Environmental
Cont/Prsv: 40mL VOA Vial/HCl Cool
Matrix: Aqueous

Lab ID: 20254-01
Batch ID: PV-0403-E
Sampled: 03-17-98
Received: 03-17-98
Analyzed: 03-19-98

PARAMETER	CONCENTRATION (ug/L)	REPORTING LIMIT (ug/L)
1,2-Dibromoethane (EDB)	0.32	0.01

BRL = Below Reporting Limit. Method Reference: Method 504.1 - 1,2-Dibromoethane (EDB), 1,2-Dibromo-3-Chloropropane (DBCP) and 1,2,3-Trichloropropane in Water by Microextraction and Gas Chromatography, US EPA EPA-600/R-95/131 (Revised 1995).

GROUNDWATER ANALYTICAL

EPA METHOD 504.1
EDB (GC/ECD)

Field ID: SV-4
Project: Otis FS-12
Client: Atlantic Environmental
Cont/Prsv: 40mL VOA Vial/HCl Cool
Matrix: Aqueous

Lab ID: 20254-02
Batch ID: PV-0403-E
Sampled: 03-17-98
Received: 03-17-98
Analyzed: 03-20-98

PARAMETER	CONCENTRATION (ug/L)	REPORTING LIMIT (ug/L)
1,2-Dibromoethane (EDB)	5.9	0.39

BRL = Below Reporting Limit. Method Reference: Method 504.1 - 1,2-Dibromoethane (EDB), 1,2-Dibromo-3-Chloropropane (DBCP) and 1,2,3-Trichloropropane in water by Microextraction and Gas Chromatography. US EPA EPA-600/R-95/131 (Revised 1995).

GROUNDWATER ANALYTICAL

EPA METHOD 504.1
EDB (GC/ECD)

Field ID: SV-8
Project: Otis FS-12
Client: Atlantic Environmental
Cont/Prsv: 40mL VOA Vial/HCl Cool
Matrix: Aqueous

Lab ID: 20254-03
Batch ID: PV-0403-E
Sampled: 03-17-98
Received: 03-17-98
Analyzed: 03-19-98

PARAMETER	CONCENTRATION (ug/L)	REPORTING LIMIT (ug/L)
1,2-Dibromoethane (EDB)	BRL	0.01

BRL = Below Reporting Limit. Method Reference: Method 504.1 - 1,2-Dibromoethane (EDB), 1,2-Dibromo-3-Chloropropane (DBCP) and 1,2,3-Trichloropropane in Water by Microextraction and Gas Chromatography, US EPA EPA-600/R-95/131 (Revised 1995).

**GROUNDWATER
ANALYTICAL**

**EPA METHOD 504.1
EDB (GC/ECD)**

Field ID: SV-13
Project: Otis FS-12
Client: Atlantic Environmental
Cont/Prsv: 40mL VOA Vial/HCl Cool
Matrix: Aqueous

Lab ID: 20254-04
Batch ID: PV-0403-E
Sampled: 03-17-98
Received: 03-17-98
Analyzed: 03-20-98

PARAMETER	CONCENTRATION (ug/L)	REPORTING LIMIT (ug/L)
1,2-Dibromoethane (EDB)	3.9	0.39

REL = Below Reporting Limit. Method Reference: Method 504.1 - 1,2-Dibromoethane (EDB), 1,2-Dibromo-3-Chloropropane (DBCP) and 1,2,3-Trichloropropane in Water by Microextraction and Gas Chromatography, US EPA EPA-600/R-95/131 (Revised 1995).

GROUNDWATER ANALYTICAL

EPA METHOD 504.1
EDB (GC/ECD)

Field ID: SV-14
Project: Otis FS-12
Client: Atlantic Environmental
Cont/Prsv: 40mL VOA Vial/HCl Cool
Matrix: Aqueous

Lab ID: 20254-05
Batch ID: PV-0403-E
Sampled: 03-17-98
Received: 03-17-98
Analyzed: 03-20-98

PARAMETER	CONCENTRATION (ug/L)	REPORTING LIMIT (ug/L)
1,2-Dibromoethane (EDB)	BRL	0.01

BRL = Below Reporting Limit. Method Reference: Method 504.1 - 1,2-Dibromoethane (EDB), 1,2-Dibromo-3-Chloropropane (DBCP) and 1,2,3-Trichloropropane in Water by Microextraction and Gas Chromatography, US EPA EPA-600/R-95/131 (Revised 1995).

GROUNDWATER ANALYTICAL

EPA METHOD 504.1
EDB (GC/ECD)

Field ID: WT-19
Project: Otis FS-12
Client: Atlantic Environmental
Cont/Prsv: 40mL VOA Vial/HCl Cool
Matrix: Aqueous

Lab ID: 20254-06
Batch ID: PV-0403-E
Sampled: 03-17-98
Received: 03-17-98
Analyzed: 03-19-98

PARAMETER	CONCENTRATION (ug/L)	REPORTING LIMIT (ug/L)
1,2-Dibromoethane (EDB)	BRL	0.01

BRL = Below Reporting Limit. Method Reference: Method 504.1 - 1,2-Dibromoethane (EDB), 1,2-Dibromo-3-Chloropropane (DBCP) and 1,2,3-Trichloropropane in water by Microextraction and Gas Chromatography, US EPA EPA-600/R-95/131 (Revised 1995).

GROUNDWATER ANALYTICAL

EPA METHOD 8015 (MA DEP Modified)
Volatile Petroleum Hydrocarbons (GC/PID/FID)

Field ID: SV-24
Project: Otis FS-12
Client: Atlantic Environmental
Cont/Prsv: 40mL VOA Vial/HCl Cool
Matrix: Aqueous

Lab ID: 20254-07
Batch ID: VG3-0759-W
Sampled: 03-17-98
Received: 03-17-98
Analyzed: 03-23-98

Volatile Petroleum Hydrocarbons

PARAMETER	CONCENTRATION (ug/L)	REPORTING LIMIT (ug/L)
n-C 5 to n-C 8 Aliphatics *	550	5
n-C 9 to n-C 12 Aliphatics	BRL	5
n-C 9 to n-C 10 Aromatics	550	5

Targeted Volatile Organic Analytes

PARAMETER	CONCENTRATION (ug/L)	REPORTING LIMIT (ug/L)
Methyl tert-butyl Ether	BRL	5
Benzene	7	1
Toluene	10	1
Ethylbenzene	96	1
meta- and para-Xylene	200	1
ortho-Xylene	49	1
Naphthalene	16	5

QC SURROGATE COMPOUND	SPIKED	MEASURED	RECOVERY	QC LIMITS
2,5-Dibromotoluene	50	44	87 %	70 - 130 %

BRL = Below Reporting Limit. * = Reported concentration excludes targeted Volatile Organic analytes. Method Reference: Method 8015 (Modified) - Nonhalogenated Volatile Organics by Gas Chromatography, Test Methods for Evaluating Solid Waste, US EPA SW-846, Third Edition (1986). Modified in accordance with the Method for the Determination of Volatile Petroleum Hydrocarbons, MA DEP, Public Comment Draft 1.0 (1995) and Issues Paper: Implementation of VPH/EPH Approach, MA DEP (1996).

GROUNDWATER ANALYTICAL

EPA METHOD 8015 (MA DEP Modified) Volatile Petroleum Hydrocarbons (GC/PID/FID)

Field ID: SV-4
Project: Otis FS-12
Client: Atlantic Environmental
Cont/Prsv: 40mL VOA Vial/HCl Cool
Matrix: Aqueous

Lab ID: 20254-08
Batch ID: VG3-0759-W
Sampled: 03-17-98
Received: 03-17-98
Analyzed: 03-23-98

Volatile Petroleum Hydrocarbons

PARAMETER	CONCENTRATION (ug/L)	REPORTING LIMIT (ug/L)
n-C 5 to n-C 8 Aliphatics *	2,000	25
n-C 9 to n-C 12 Aliphatics	BRL	25
n-C 9 to n-C 10 Aromatics	970	25

Targeted Volatile Organic Analytes

PARAMETER	CONCENTRATION (ug/L)	REPORTING LIMIT (ug/L)
Methyl tert-butyl Ether	BRL	25
Benzene	32	5
Toluene	2,700	5
Ethylbenzene	160	5
meta- and para-Xylene	440	5
ortho-Xylene	170	5
Naphthalene	36	25

QC SURROGATE COMPOUND	SPIKED	MEASURED	RECOVERY	QC LIMITS
2,5-Dibromotoluene	50	43	86 %	70 - 130 %

BRL = Below Reporting Limit. * = Reported concentration excludes targeted Volatile Organic analytes. Method Reference: Method 8015 (Modified) - Nonhalogenated Volatile Organics by Gas Chromatography, Test Methods for Evaluating Solid Waste, US EPA SW-846, Third Edition (1985). Modified in accordance with the Method for the Determination of Volatile Petroleum Hydrocarbons, MA DEP, Public Comment Draft 1.0 (1995) and Issues Paper: Implementation of VPH/EPH Approach, MA DEP (1996).

GROUNDWATER ANALYTICAL

EPA METHOD 8015 (MA DEP Modified) Volatile Petroleum Hydrocarbons (GC/PID/FID)

Field ID: SV-8
Project: Otis FS-12
Client: Atlantic Environmental
Cont/Prsv: 40mL VOA Vial/HCl Cool
Matrix: Aqueous

Lab ID: 20254-09
Batch ID: VG3-0759-W
Sampled: 03-17-98
Received: 03-17-98
Analyzed: 03-23-98

Volatile Petroleum Hydrocarbons

PARAMETER	CONCENTRATION (ug/L)	REPORTING LIMIT (ug/L)
n-C 5 to n-C 8 Aliphatics *	700	5
n-C 9 to n-C 12 Aliphatics	78	5
n-C 9 to n-C 10 Aromatics	510	5

Targeted Volatile Organic Analytes

PARAMETER	CONCENTRATION (ug/L)	REPORTING LIMIT (ug/L)
Methyl tert-butyl Ether	BRL	5
Benzene	BRL	1
Toluene	17	1
Ethylbenzene	7	1
meta- and para-Xylene	37	1
ortho-Xylene	19	1
Naphthalene	BRL	5

QC SURROGATE COMPOUND	SPIKED	MEASURED	RECOVERY	QC LIMITS
2,5-Dibromotoluene	50	46	92 %	70 - 130 %

BRL = Below Reporting Limit. * = Reported concentration excludes targeted Volatile Organic analytes. Method Reference: Method 8015 (Modified) - Nonhalogenated Volatile Organics by Gas Chromatography. Test Methods for Evaluating Solid Waste, US EPA SW-846, Third Edition (1986). Modified in accordance with the Method for the Determination of Volatile Petroleum Hydrocarbons, MA DEP, Public Comment Draft 1.0 (1995) and Issues Paper: Implementation of VPH/EPH Approach, MA DEP (1996).

GROUNDWATER ANALYTICAL

EPA METHOD 8015 (MA DEP Modified) Volatile Petroleum Hydrocarbons (GC/PID/FID)

Field ID: SV-13
Project: Otis FS-12
Client: Atlantic Environmental
Cont/Prsv: 40mL VOA Vial/HCl Cool
Matrix: Aqueous

Lab ID: 20254-10
Batch ID: VG3-0759-W
Sampled: 03-17-98
Received: 03-17-98
Analyzed: 03-23-98

Volatile Petroleum Hydrocarbons

PARAMETER	CONCENTRATION (ug/L)	REPORTING LIMIT (ug/L)
n-C 5 to n-C 8 Aliphatics *	1,600	25
n-C 9 to n-C 12 Aliphatics	BRL	25
n-C 9 to n-C 10 Aromatics	2,300	25

Targeted Volatile Organic Analytes

PARAMETER	CONCENTRATION (ug/L)	REPORTING LIMIT (ug/L)
Methyl tert-butyl Ether	BRL	25
Benzene	68	5
Toluene	1,600	5
Ethylbenzene	280	5
meta- and para-Xylene	1,100	5
ortho-Xylene	520	5
Naphthalene	56	25

QC SURROGATE COMPOUND	SPIKED	MEASURED	RECOVERY	QC LIMITS
2,5-Dibromotoluene	50	38	77 %	70 - 130 %

BRL = Below Reporting Limit. * = Reported concentration excludes targeted Volatile Organic analytes. Method Reference: Method 8015 (Modified) - Monohalogenated Volatile Organics by Gas Chromatography, Test Methods for Evaluating Solid Waste, US EPA SW-846, Third Edition (1986). Modified in accordance with the Method for the Determination of Volatile Petroleum Hydrocarbons, MA DEP, Public Comment Draft 1.0 (1995) and Issues Paper: Implementation of VPH/EPH Approach, MA DEP (1996).

GROUNDWATER ANALYTICAL

EPA METHOD 8015 (MA DEP Modified) Volatile Petroleum Hydrocarbons (GC/PID/FID)

Field ID: SV-14
Project: Otis FS-12
Client: Atlantic Environmental
Cont/Prsv: 40mL VOA Vial/HCl Cool
Matrix: Aqueous

Lab ID: 20254-11
Batch ID: VG1-0434-W
Sampled: 03-17-98
Received: 03-17-98
Analyzed: 03-25-98

Volatile Petroleum Hydrocarbons

PARAMETER	CONCENTRATION (ug/L)	REPORTING LIMIT (ug/L)
n-C 5 to n-C 8 Aliphatics *	810	5
n-C 9 to n-C 12 Aliphatics	170	5
n-C 9 to n-C 10 Aromatics	95	5

Targeted Volatile Organic Analytes

PARAMETER	CONCENTRATION (ug/L)	REPORTING LIMIT (ug/L)
Methyl tert-butyl Ether	BRL	5
Benzene	BRL	1
Toluene	16	1
Ethylbenzene	10	1
meta- and para-Xylene	35	1
ortho-Xylene	14	1
Naphthalene	5	5

QC SURROGATE COMPOUND	SPIKED	MEASURED	RECOVERY	QC LIMITS
2,5-Dibromotoluene	50	50	100 %	70 - 130 %

BRL = Below Reporting Limit. * = Reported concentration excludes targeted Volatile Organic analytes. Method Reference: Method 8015 (Modified) - Nonhalogenated Volatile Organics by Gas Chromatography. Test Methods for Evaluating Solid Waste, US EPA SW-846, Third Edition (1986). Modified in accordance with the Method for the Determination of Volatile Petroleum Hydrocarbons, MA DEP, Public Comment Draft 1.0 (1995) and Issues Paper: Implementation of VPH/EPH Approach, MA DEP (1996).

GROUNDWATER ANALYTICAL

EPA METHOD 8015 (MA DEP Modified) Volatile Petroleum Hydrocarbons (GC/PID/FID)

Field ID: WT-19
Project: Otis FS-12
Client: Atlantic Environmental
Cont/Prsv: 40mL VOA Vial/HCl Cool
Matrix: Aqueous

Lab ID: 20254-12
Batch ID: VG3-0759-W
Sampled: 03-17-98
Received: 03-17-98
Analyzed: 03-23-98

Volatile Petroleum Hydrocarbons

PARAMETER	CONCENTRATION (ug/L)	REPORTING LIMIT (ug/L)
n-C 5 to n-C 8 Aliphatics *	93	5
n-C 9 to n-C 12 Aliphatics	BRL	5
n-C 9 to n-C 10 Aromatics	740	5

Targeted Volatile Organic Analytes

PARAMETER	CONCENTRATION (ug/L)	REPORTING LIMIT (ug/L)
Methyl tert-butyl Ether	BRL	5
Benzene	BRL	1
Toluene	5	1
Ethylbenzene	3	1
meta- and para-Xylene	57	1
ortho-Xylene	52	1
Naphthalene	12	5

QC SURROGATE COMPOUND	SPIKED	MEASURED	RECOVERY	QC LIMITS
2,5-Dibromotoluene	50	45	91 %	70 - 130 %

BRL = Below Reporting Limit. * = Reported concentration excludes targeted Volatile Organic analytes. Method Reference: Method 8015 (Modified) - Nonhalogenated Volatile Organics by Gas Chromatography. Test Methods for Evaluating Solid Waste, US EPA SW-846, Third Edition (1986). Modified in accordance with the Method for the Determination of Volatile Petroleum Hydrocarbons, MA DEP, Public Comment Draft 1.0 (1995) and Issues Paper: Implementation of VPH/EPH Approach, MA DEP (1996).

GROUNDWATER ANALYTICAL

EPA METHOD 8100 (MA DEP Modified)
Extractable Petroleum Hydrocarbons (GC/FID)

Field ID: SV-24
Project: Otis FS-12
Client: Atlantic Environmental
Cont/Prsv: 1L Glass/H2SO4 Cool
Matrix: Aqueous

Lab ID: 20254-13
Batch ID: EP-0260-F
Sampled: 03-17-98
Received: 03-17-98
Extracted: 03-20-98
Analyzed: 03-27-98

Extractable Petroleum Hydrocarbons

PARAMETER	CONCENTRATION (ug/L)		REPORTING LIMIT (ug/L)	
n-C 9 to n-C 18 Aliphatics	BRL		500	
n-C 19 to n-C 36 Aliphatics	BRL		500	
n-C 11 to n-C 22 Aromatics *	BRL		200	
QC SURROGATE COMPOUND	SPIKED	MEASURED	RECOVERY	QC LIMITS
Chloro-octadecane	38	29	77 %	40 - 140 %
o-Terphenyl	38	25	67 %	40 - 140 %

BRL = Below Reporting Limit. * * Reported concentration excludes targeted Polynuclear Aromatic Hydrocarbon analytes. Method Reference: Method 8100 (Modified) - Polynuclear Aromatic Hydrocarbons, Test Methods for Evaluating Solid Waste, US EPA SW-846, Third Edition (1986). Modified in accordance with the Method for the Determination of Extractable Petroleum Hydrocarbons, MA DEP, Public Comment Draft 1.0 (1995) and Issues Paper: Implementation of VPH/EPH Approach, MA DEP (1996). Reported parameter list abbreviated to exclude the targeted Polynuclear Aromatic Hydrocarbon analytes.

GROUNDWATER ANALYTICAL

EPA METHOD 8100 (MA DEP Modified) Extractable Petroleum Hydrocarbons (GC/FID)

Field ID: SV-4
Project: Otis FS-12
Client: Atlantic Environmental
Cont/Prsv: 1L Glass/H2SO4 Cool
Matrix: Aqueous

Lab ID: 20254-14
Batch ID: EP-0260-F
Sampled: 03-17-98
Received: 03-17-98
Extracted: 03-20-98
Analyzed: 03-27-98

Extractable Petroleum Hydrocarbons

PARAMETER	CONCENTRATION (ug/L)		REPORTING LIMIT (ug/L)	
n-C 9 to n-C 18 Aliphatics	BRL		500	
n-C 19 to n-C 36 Aliphatics	BRL		500	
n-C 11 to n-C 22 Aromatics *	BRL		200	
QC SURROGATE COMPOUND	SPIKED	MEASURED	RECOVERY	QC LIMITS
Chloro-octadecane	40	30	76 %	40 - 140 %
o-Terphenyl	40	26	66 %	40 - 140 %

BRL = Below Reporting Limit. * = Reported concentration excludes targeted Polynuclear Aromatic Hydrocarbon analytes. Method Reference: Method 8100 (Modified) - Polynuclear Aromatic Hydrocarbons, Test Methods for Evaluating Solid Waste, US EPA SW-846, Third Edition (1986). Modified in accordance with the Method for the Determination of Extractable Petroleum Hydrocarbons, MA DEP, Public Comment Draft 1.0 (1995) and Issues Paper: Implementation of VPH/EPH Approach, MA DEP (1996). Reported parameter list abbreviated to exclude the targeted Polynuclear Aromatic Hydrocarbon analytes.

GROUNDWATER ANALYTICAL

EPA METHOD 8100 (MA DEP Modified) Extractable Petroleum Hydrocarbons (GC/FID)

Field ID: SV-8
Project: Otis FS-12
Client: Atlantic Environmental
Cont/Prsv: 1L Glass/H2SO4 Cool
Matrix: Aqueous

Lab ID: 20254-15
Batch ID: EP-0260-F
Sampled: 03-17-98
Received: 03-17-98
Extracted: 03-20-98
Analyzed: 03-27-98

Extractable Petroleum Hydrocarbons

PARAMETER	CONCENTRATION (ug/L)		REPORTING LIMIT (ug/L)	
n-C 9 to n-C 18 Aliphatics	BRL		500	
n-C 19 to n-C 36 Aliphatics	BRL		500	
n-C 11 to n-C 22 Aromatics *	BRL		200	
QC SURROGATE COMPOUND	SPIKED	MEASURED	RECOVERY	QC LIMITS
Chloro-octadecane	38	32	83 %	40 - 140 %
o-Terphenyl	38	30	79 %	40 - 140 %

BRL = Below Reporting Limit. * = Reported concentration excludes targeted Polynuclear Aromatic Hydrocarbon analytes. Method Reference: Method 8100 (Modified) - Polynuclear Aromatic Hydrocarbons, Test Methods for Evaluating Solid Waste, US EPA SW-846, Third Edition (1986). Modified in accordance with the Method for the Determination of Extractable Petroleum Hydrocarbons, MA DEP, Public Comment Draft 1.0 (1995) and Issues Paper: Implementation of VPH/EPH Approach, MA DEP (1996). Reported parameter list abbreviated to exclude the targeted Polynuclear Aromatic Hydrocarbon analytes.

**GROUNDWATER
ANALYTICAL****EPA METHOD 8100 (MA DEP Modified)
Extractable Petroleum Hydrocarbons (GC/FID)**

Field ID: SV-13
 Project: Otis FS-12
 Client: Atlantic Environmental
 Cont/Prsv: 1L Glass/H2SO4 Cool
 Matrix: Aqueous

Lab ID: 20254-16
 Batch ID: EP-0260-F
 Sampled: 03-17-98
 Received: 03-17-98
 Extracted: 03-20-98
 Analyzed: 03-27-98

Extractable Petroleum Hydrocarbons

PARAMETER	CONCENTRATION (ug/L) -		REPORTING LIMIT (ug/L)	
n-C 9 to n-C 18 Aliphatics		BRL		500
n-C 19 to n-C 36 Aliphatics		BRL		500
n-C 11 to n-C 22 Aromatics *		200		200
QC SURROGATE COMPOUND	SPIKED	MEASURED	RECOVERY	QC LIMITS
Chloro-octadecane	38	33	87 %	40 - 140 %
o-Terphenyl	38	27	72 %	40 - 140 %

BRL = Below Reporting Limit. * = Reported concentration excludes targeted Polynuclear Aromatic Hydrocarbon analytes. Method Reference: Method 8100 (Modified) - Polynuclear Aromatic Hydrocarbons, Test Methods for Evaluating Solid Waste, US EPA SW-846, Third Edition (1986). Modified in accordance with the Method for the Determination of Extractable Petroleum Hydrocarbons, MA DEP, Public Comment Draft 1.0 (1995) and Issues Paper: Implementation of VPH/EPH Approach, MA DEP (1996). Reported parameter list abbreviated to exclude the targeted Polynuclear Aromatic Hydrocarbon analytes.

**GROUNDWATER
ANALYTICAL****QUALITY ASSURANCE
Project Narrative**

Project: Otis FS-12
Client: Atlantic Environmental

Lab ID: 20254
Received: 03-17-98

A. Physical Condition of Sample(s)

This project was received by the laboratory in satisfactory condition. The sample(s) were received undamaged in appropriate containers with the correct preservation.

B. Project Documentation

This project was accompanied by satisfactory Chain of Custody documentation. The sample container label(s) agreed with the Chain of Custody.

C. Analysis of Sample(s)

No analytical anomalies or non-conformances were noted by the laboratory during the processing of these samples. All data contained within this report are released without qualification.

GROUNDWATER ANALYTICAL

EPA METHOD 8100 (MA DEP Modified)
Extractable Petroleum Hydrocarbons (GC/FID)

Field ID: SV-14
Project: Otis FS-12
Client: Atlantic Environmental
Cont/Prsv: 1L Glass/H2SO4 Cool
Matrix: Aqueous

Lab ID: 20254-17
Batch ID: EP-0260-F
Sampled: 03-17-98
Received: 03-17-98
Extracted: 03-20-98
Analyzed: 03-27-98

Extractable Petroleum Hydrocarbons

PARAMETER	CONCENTRATION (ug/L)		REPORTING LIMIT (ug/L)	
n-C 9 to n-C 18 Aliphatics	1,100		500	
n-C 19 to n-C 36 Aliphatics		BRL	500	
n-C 11 to n-C 22 Aromatics *	210		200	
QC SURROGATE COMPOUND	SPIKED	MEASURED	RECOVERY	QC LIMITS
Chloro-octadecane	38	28	73 %	40 - 140 %
o-Terphenyl	38	27	72 %	40 - 140 %

BRL = Below Reporting Limit. * = Reported concentration excludes targeted Polynuclear Aromatic Hydrocarbon analytes. Method Reference: Method 8100 (Modified) - Polynuclear Aromatic Hydrocarbons, Test Methods for Evaluating Solid Waste, US EPA SW-846, Third Edition (1986). Modified in accordance with the Method for the Determination of Extractable Petroleum Hydrocarbons, MA DEP, Public Comment Draft 1.0 (1995) and Issues Paper: Implementation of VPH/EPH Approach, MA DEP (1996). Reported parameter list abbreviated to exclude the targeted Polynuclear Aromatic Hydrocarbon analytes.

GROUNDWATER ANALYTICAL

EPA METHOD 8100 (MA DEP Modified)
Extractable Petroleum Hydrocarbons (GC/FID)

Field ID: WT-19
Project: Otis FS-12
Client: Atlantic Environmental
Cont/Prsv: 1L Glass/H2SO4 Cool
Matrix: Aqueous

Lab ID: 20254-18
Batch ID: EP-0260-F
Sampled: 03-17-98
Received: 03-17-98
Extracted: 03-20-98
Analyzed: 03-27-98

Extractable Petroleum Hydrocarbons

PARAMETER	CONCENTRATION (ug/L)		REPORTING LIMIT (ug/L)	
n-C 9 to n-C 18 Aliphatics	BRL		500	
n-C 19 to n-C 36 Aliphatics	BRL		500	
n-C 11 to n-C 22 Aromatics *	BRL		200	
QC SURROGATE COMPOUND	SPIKED	MEASURED	RECOVERY	QC LIMITS
Chloro-octadecane	38	24	64 %	40 - 140 %
o-Terphenyl	38	22	57 %	40 - 140 %

BRL = Below Reporting Limit. * = Reported concentration excludes targeted Polynuclear Aromatic Hydrocarbon analytes. Method Reference: Method 8100 (Modified) - Polynuclear Aromatic Hydrocarbons, Test Methods for Evaluating Solid Waste, US EPA SW-846, Third Edition (1986). Modified in accordance with the Method for the Determination of Extractable Petroleum Hydrocarbons, MA DEP, Public Comment Draft 1.0 (1995) and Issues Paper: Implementation of VPH/EPH Approach, MA DEP (1996). Reported parameter list abbreviated to exclude the targeted Polynuclear Aromatic Hydrocarbon analytes.

APPENDIX C

**Analytical Results for Soil Samples Collected from
Borings SB-1 through SB-10**

MMR/FS-12
Soils Analysis
EPII/VPII, BTEX, EDB Concentrations
2/10/98 - 2/20/98

SAMPLE #	DEPTH	VPH - Concentrations			EPH - Concentrations		
		C5-C8	C9-C12	C9-C10	C9 - C18	C19 - C36	C11 - C22
		Aliphatics	Aliphatics	Aromatics	Aliphatics	Aliphatics	Aromatics
SB-1	83-85	0.32	BRL	BRL	BRL	62.00	33.00
SB-1	88-90	BRL	BRL	BRL	BRL	BRL	BRL
SB-1	96-98	300.00	160.00	240.00	1900.00	BRL	200.00
SB-1	101-103	15.00	15.00	6.90	260.00	BRL	BRL
MA DEP Cleanup Standards For Soil							
S-1/GW-1		100.00	1000.00	100.00	1000.00	2500.00	200.00
S-3/GW-1		500.00	5000.00	100.00	5000.00	5000.00	200.00
<div> <div>← 15 FT BG And Below</div> </div>							
Sample	Depth	Benzene		Toluene	Ethyl-Benzene	Xylene	
SB-1	83-85		BRL	BRL	BRL		BRL
SB-1	88-90		BRL	BRL	BRL		BRL
SB-1	96-98		BRL	2.10	2.70		7.80
SB-1	101-103		BRL	0.18	0.15		0.49
MA DEP Cleanup Standards For Soil							
S-1/GW-1			10.00	90.00	80.00		500.00
S-3/GW-1			10.00	90.00	80.00		800.00
Sample	Depth	EDB					
SB-1	83-85						BRL
SB-1	88-90						BRL
SB-1	96-98						BRL
SB-1	101-103						BRL
MA DEP Cleanup Standards For Soil							
S-1/GW-1							0.005
S-3/GW-1							0.005

BRL = Below Reportable Limits of Laboratory

All units in mg/kg (ppm)

MMR/FS-12
Soils Analysis
VPH/EPH, BTEX, EDB Concentrations
2/10/98 - 2/20/98

VPH - Concentrations					EPH - Concentrations		
SAMPLE #	DEPTH	C5-C8	C9-C12	C9-C10	C9 - C18	C19 - C36	C11 - C22
		Aliphatics	Aliphatics	Aromatics	Aliphatics	Aliphatics	Aromatics
SB-2	82-84	0.41	BRL	BRL	BRL	BRL	BRL
SB-2	87-89	BRL	BRL	BRL	BRL	BRL	BRL
SB-2	95-97	BRL	BRL	0.31	BRL	BRL	BRL
SB-2	97-103	0.71	0.95	BRL	BRL	BRL	BRL
MA DEP Cleanup Standards For Soil							
S-1/GW-1		100	1000	100	1000	2500	200
S-3/GW-1		500	5000	100	5000	5000	200
Sample	Depth			Benzene	Toluene	Ethyl-Benzene	Xylene
SB-2		82-84		BRL	BRL	BRL	0.58
SB-2		87-89		BRL	BRL	BRL	BRL
SB-2		95-97		BRL	BRL	BRL	BRL
SB-2		97-103		BRL	BRL	BRL	BRL
MA DEP Cleanup Standards For Soil							
S-1/GW-1				10	90	80	500
S-3/GW-1				10	90	80	800
Sample	Depth					EDB	
SB-2		82-84				BRL	
SB-2		87-89				BRL	
SB-2		95-97				BRL	
SB-2		97-103				BRL	
MA DEP Cleanup Standards For Soil							
S-1/GW-1						0.005	
S-3/GW-1						0.005	

BRL = Below Reportable Limits of Laboratory

All units in mg/kg (ppm)

MMR/FS-12
Soils Analysis
VPH/EPH, BTEX, EDB Concentrations
2/10/98 - 2/20/98

SAMPLE #	DEPTH	VPH - Concentrations			EPH - Concentrations		
		C5-C8	C9-C12	C9-C10	C9 - C18	C19 - C36	C11 - C22
		Aliphatics	Aliphatics	Aromatics	Aliphatics	Aliphatics	Aromatics
SB-3	78-83	0.45	0.65	BRL	BRL	0.04	BRL
SB-3	83-88	BRL	BRL	BRL	BRL	BRL	BRL
SB-3	88-93	1.60	BRL	BRL	BRL	BRL	BRL
SB-3	93-98	0.43	BRL	BRL	BRL	BRL	BRL
MA DEP Cleanup Standards For Soil							
S-1/GW-1		100	1000	100	1000	2500	200
S-3/GW-1		500	5000	100	5000	5000	200
Sample	Depth	Benzene		Toluene	Ethyl-Benzene	Xylene	
SB-3	78-83	BRL	BRL	BRL	BRL	0.056	
SB-3	83-88	BRL	BRL	BRL	BRL	BRL	
SB-3	88-93	BRL	0.06	BRL	BRL	BRL	
SB-3	93-98	BRL	BRL	BRL	BRL	BRL	
MA DEP Cleanup Standards For Soil							
S-1/GW-1		10	90	80	500		
S-3/GW-1		10	90	80	800		
Sample	Depth	EDB					
SB-3	78-83					BRL	
SB-3	83-88					BRL	
SB-3	88-93					BRL	
SB-3	93-98					BRL	
MA DEP Cleanup Standards For Soil							
S-1/GW-1						0.005	
S-3/GW-1						0.005	

BRL = Below Reportable Limits of Laboratory

All units in mg/kg (ppm)

MMR/FS-12
Soils Analysis
VPH/EPH, BTEX, EDB Concentrations
2/10/98 - 2/20/98

		VPH - Concentrations			EPH - Concentrations		
SAMPLE #	DEPTH	C5-C8	C9-C12	C9-C10	C9 - C18	C19 - C36	C11 - C22
		Aliphatics	Aliphatics	Aromatics	Aliphatics	Aliphatics	Aromatics
SB-4	81-83	BRL	BRL	BRL	BRL	BRL	BRL
SB-4	86-88	0.28	BRL	BRL	BRL	BRL	BRL
SB-4	94-96	BRL	0.76	BRL	BRL	BRL	BRL
SB-4	99-101	BRL	BRL	BRL	BRL	BRL	BRL
MA DEP Cleanup Standards For Soil							
S-1/GW-1		100	1000	100	1000	2500	200
S-3/GW-1		500	5000	100	5000	5000	200
MA DEP Cleanup Standards For Soil							
Sample	Depth	Benzene		Toluene	Ethyl-Benzene	Xylene	
SB-4	81-83		BRL	BRL	BRL		BRL
SB-4	86-88		BRL	BRL	BRL		BRL
SB-4	94-96		BRL	BRL	BRL		BRL
SB-4	99-101		BRL	BRL	BRL		BRL
MA DEP Cleanup Standards For Soil							
S-1/GW-1			10	90	80		500
S-3/GW-1			10	90	80		800
MA DEP Cleanup Standards For Soil							
Sample	Depth	EDB					
SB-4	81-83						BRL
SB-4	86-88						BRL
SB-4	94-96						BRL
SB-4	99-101						BRL
MA DEP Cleanup Standards For Soil							
S-1/GW-1							0.005
S-3/GW-1							0.005

BRL = Below Reportable Limits of Laboratory

All units in mg/kg (ppm)

MMR/FS-12
Soils Analysis
VPII/EPH, BTEX, EDB Concentrations
2/10/98 - 2/20/98

SAMPLE #	DEPTH	VPH - Concentrations			EPH - Concentrations		
		C5-C8	C9-C12	C9-C10	C9 - C18	C19 - C36	C11 - C22
		Aliphatics	Aliphatics	Aromatics	Aliphatics	Aliphatics	Aromatics
SB-5	81-86	BRL	BRL	BRL	BRL	BRL	BRL
SB-5	86-91	1.20	15.00	7.40	0.10	BRL	BRL
SB-5	91-96	390.00	99.00	71.00	0.09	BRL	BRL
SB-5	96-101	910.00	130.00	170.00	0.36	BRL	0.05
MA DEP Cleanup Standards For Soil							
S-1/GW-1		100	1000	100	1000	2500	200
S-3/GW-1		500	5000	100	5000	5000	200
Sample	Depth	Benzene		Toluene	Ethyl-Benzene	Xylene	
SB-5	81-86		BRL	BRL	BRL	BRL	BRL
SB-5	86-91		BRL	BRL	BRL	BRL	BRL
SB-5	91-96		BRL	9	4.7		15.2
SB-5	96-101		BRL	24	8.1		26.5
MA DEP Cleanup Standards For Soil							
S-1/GW-1			10	90	80		500
S-3/GW-1			10	90	80		800
Sample	Depth	EDB					
SB-5	81-86					BRL	
SB-5	86-91					BRL	
SB-5	91-96					BRL	
SB-5	96-101					BRL	
MA DEP Cleanup Standards For Soil							
S-1/GW-1						0.005	
S-3/GW-1						0.005	

BRL = Below Reportable Limits of Laboratory

All units in mg/kg (ppm)

MMR/FS-12
Soils Analysis
VPH/EPH, BTEX, EDB Concentrations
2/10/98 - 2/20/98

SAMPLE #	DEPTH	VPH - Concentrations			EPH - Concentrations		
		C5-C8	C9-C12	C9-C10	C9 - C18	C19 - C36	C11 - C22
		Aliphatics	Aliphatics	Aromatics	Aliphatics	Aliphatics	Aromatics
SB-6	79-84	0.54	1.50	0.53	BRL	BRL	BRL
SB-6	84-89	0.49	0.91	0.35	BRL	BRL	BRL
SB-6	89-94	0.38	BRL	BRL	BRL	BRL	BRL
SB-6	94-99	42.00	14.00	10.00	0.27	BRL	0.04
MA DEP Cleanup Standards For Soil							
S-1/GW-1		100	1000	100	1000	2500	200
S-3/GW-1		500	5000	100	5000	5000	200
MA DEP Cleanup Standards For Soil							
Sample	Depth	Benzene		Toluene	Ethyl-Benzene	Xylene	
SB-6	79-84	BRL	BRL	BRL	BRL	BRL	BRL
SB-6	84-89	BRL	BRL	BRL	BRL	BRL	BRL
SB-6	89-94	BRL	BRL	BRL	BRL	BRL	BRL
SB-6	94-99	BRL	0.28	0.27	0.48		
MA DEP Cleanup Standards For Soil							
S-1/GW-1		10	90	80	500		
S-3/GW-1		10	90	80	800		
MA DEP Cleanup Standards For Soil							
Sample	Depth	EDB					
SB-6	79-84					BRL	
SB-6	84-89					BRL	
SB-6	89-94					BRL	
SB-6	94-99					BRL	
MA DEP Cleanup Standards For Soil							
S-1/GW-1						0.005	
S-3/GW-1						0.005	

BRL = Below Reportable Limits of Laboratory

All units in mg/kg (ppm)

MMR/FS-12
Soils Analysis
VPH/EPH, BTEX, EDB Concentrations
2/10/98 - 2/20/98

SAMPLE #	DEPTH	VPH - Concentrations			EPH - Concentrations		
		C5-C8	C9-C12	C9-C10	C9 - C18	C19 - C36	C11 - C22
		Aliphatics	Aliphatics	Aromatics	Aliphatics	Aliphatics	Aromatics
SB-7	78-83	0.65	BRL	BRL	BRL	BRL	BRL
SB-7	83-88	0.38	BRL	BRL	BRL	BRL	BRL
SB-7	88-93	2.80	15.00	7.20	0.04	BRL	BRL
SB-7	93-98	38.00	17.00	6.50	0.06	BRL	BRL
MA DEP Cleanup Standards For Soil							
S-1/GW-1		100	1000	100	1000	2500	200
S-3/GW-1		500	5000	100	5000	5000	200
Sample	Depth	Benzene		Toluene	Ethyl- Benzene	Xylene	
SB-7	78-83		BRL	BRL	BRL		BRL
SB-7	83-88		BRL	BRL	BRL		BRL
SB-7	88-93		BRL	0.12	0.65		BRL
SB-7	93-98		BRL	2	0.37		0.111
MA DEP Cleanup Standards For Soil							
S-1/GW-1			10	90	80		500
S-3/GW-1			10	90	80		800
Sample	Depth	EDB					
SB-7	78-83						BRL
SB-7	83-88						BRL
SB-7	88-93						BRL
SB-7	93-98						BRL
MA DEP Cleanup Standards For Soil							
S-1/GW-1							0.005
S-3/GW-1							0.005

BRL = Below Reportable Limits of Laboratory

All units in mg/kg (ppm)

MMR/FS-12
Soils Analysis
VPH/EPH, BTEX, EDB Concentrations
2/10/98 - 2/20/98

SAMPLE #	DEPTH	VPH - Concentrations			EPH - Concentrations		
		C5-C8	C9-C12	C9-C10	C9 - C18	C19 - C36	C11 - C22
		Aliphatics	Aliphatics	Aromatics	Aliphatics	Aliphatics	Aromatics
SB-8	78-83	BRL	BRL	BRL	BRL	BRL	BRL
SB-8	83-88	BRL	BRL	BRL	BRL	BRL	BRL
SB-8	88-93	0.34	BRL	BRL	BRL	BRL	BRL
SB-8	93-98	0.36	BRL	BRL	BRL	BRL	BRL
MA DEP Cleanup Standards For Soil							
S-1/GW-1		100	1000	100	1000	2500	200
S-3/GW-1		500	5000	100	5000	5000	200
MA DEP Cleanup Standards For Soil							
Sample	Depth	Benzene		Toluene	Ethyl-Benzene	Xylene	
SB-8	78-83	BRL	BRL	BRL	BRL	BRL	BRL
SB-8	83-88	BRL	BRL	BRL	BRL	BRL	BRL
SB-8	88-93	BRL	0.082	BRL	0.063	BRL	BRL
SB-8	93-98	BRL	BRL	0.063	BRL	BRL	BRL
MA DEP Cleanup Standards For Soil							
S-1/GW-1		10	90	80	500		
S-3/GW-1		10	90	80	800		
MA DEP Cleanup Standards For Soil							
Sample	Depth	EDB					
SB-8	78-83	BRL	BRL	BRL	BRL	BRL	BRL
SB-8	83-88	BRL	BRL	BRL	BRL	BRL	BRL
SB-8	88-93	BRL	BRL	BRL	BRL	BRL	BRL
SB-8	93-98	BRL	BRL	BRL	BRL	BRL	BRL
MA DEP Cleanup Standards For Soil							
S-1/GW-1		0.005					
S-3/GW-1		0.005					

BRL = Below Reportable Limits of Laboratory

All units in mg/kg (ppm)

MMR/FS-12
Soils Analysis
VPH/EPH, BTEX, EDB Concentrations
2/10/98 - 2/20/98

SAMPLE #	DEPTH	VPH - Concentrations			EPH - Concentrations		
		C5-C8 Aliphatics	C9-C12 Aliphatics	C9-C10 Aromatics	C9 - C18 Aliphatics	C19 - C36 Aliphatics	C11 - C22 Aromatics
SB-9	75-80	BRL	BRL	BRL	BRL	BRL	BRL
SB-9	80-85	BRL	BRL	BRL	BRL	BRL	BRL
SB-9	85-90	BRL	BRL	BRL	BRL	BRL	BRL
SB-9	90-95	BRL	BRL	BRL	BRL	BRL	BRL
MA DEP Cleanup Standards For Soil							
S-1/GW-1		100	1000	100	1000	2500	200
S-3/GW-1		500	5000	100	5000	5000	200
MA DEP Cleanup Standards For Soil							
Sample	Depth	Benzene		Toluene	Ethyl- Benzene	Xylene	
SB-9	75-80	BRL	BRL	BRL	BRL	BRL	BRL
SB-9	80-85	BRL	BRL	BRL	BRL	BRL	BRL
SB-9	85-90	BRL	BRL	BRL	BRL	BRL	BRL
SB-9	90-95	BRL	BRL	BRL	BRL	BRL	BRL
MA DEP Cleanup Standards For Soil							
S-1/GW-1		10	90	80	500		
S-3/GW-1		10	90	80	800		
MA DEP Cleanup Standards For Soil							
Sample	Depth	EDB					
SB-9	75-80	BRL	BRL	BRL	BRL	BRL	BRL
SB-9	80-85	BRL	BRL	BRL	BRL	BRL	BRL
SB-9	85-90	BRL	BRL	BRL	BRL	BRL	BRL
SB-9	90-95	BRL	BRL	BRL	BRL	BRL	BRL
MA DEP Cleanup Standards For Soil							
S-1/GW-1		0.005	0.005	0.005	0.005	0.005	0.005
S-3/GW-1		0.005	0.005	0.005	0.005	0.005	0.005

BRL = Below Reportable Limits of Laboratory

All units in mg/kg (ppm)

MMR/FS-12
Soils Analysis
VPH/EPH, BTEX, EDB Concentrations
2/10/98 - 2/20/98

		VPH - Concentrations			EPH - Concentrations		
SAMPLE #	DEPTH	C5-C8	C9-C12	C9-C10	C9 - C18	C19 - C36	C11 - C22
		Aliphatics	Aliphatics	Aromatics	Aliphatics	Aliphatics	Aromatics
SB-10	77-83	BRL	BRL	BRL	BRL	BRL	BRL
SB-10	83-88	BRL	BRL	BRL	BRL	BRL	BRL
SB-10	88-93	BRL	BRL	BRL	BRL	BRL	BRL
SB-10	93-98	BRL	BRL	BRL	BRL	BRL	BRL
MA DEP Cleanup Standards For Soil							
S-1/GW-1		100	1000	100	1000	2500	200
S-3/GW-1		500	5000	100	5000	5000	200
MA DEP Cleanup Standards For Soil							
Sample	Depth	Benzene		Toluene	Ethyl-Benzene	Xylene	
SB-10	77-83		BRL	BRL	BRL		BRL
SB-10	83-88		BRL	BRL	BRL		BRL
SB-10	88-93		BRL	BRL	BRL		BRL
SB-10	93-98		BRL	BRL	BRL		BRL
MA DEP Cleanup Standards For Soil							
S-1/GW-1			10	90	80		500
S-3/GW-1			10	90	80		800
MA DEP Cleanup Standards For Soil							
Sample	Depth	EDB					
SB-10	77-83					BRL	
SB-10	83-88					BRL	
SB-10	88-93					BRL	
SB-10	93-98					BRL	
MA DEP Cleanup Standards For Soil							
S-1/GW-1						0.005	
S-3/GW-1						0.005	

BRL = Below Reportable Limits of Laboratory

All units in mg/kg (ppm)

APPENDIX D

**Letter (with attachments) from M.C. Wheeler and B.T. Sullivan, HAZWRAP,
to Dan Santos, Martin Marietta Energy Systems, Subject: FS-12 Free Product Investigation,
dated March 11, 1993**

MARTIN MARIETTA ENERGY SYSTEMS, INC.

POST OFFICE BOX 2003
OAK RIDGE, TENNESSEE 37831

March 11, 1993

Mr. Daniel Santos
Installation Restoration Program
197 Granville Avenue
Box 41
Otis Air National Guard Base, Massachusetts 02542-5028

Dear Dan:

FS-12 Free Product Investigation

Attached are three copies of a Technical Memorandum (TM) regarding the FS-12 Free Product Investigation. The TM was prepared by Advanced Sciences, Inc., and reviewed by the Hazardous Waste Remedial Actions Program. The information presented in the TM will be discussed in greater detail in the Sandwich Remedial Investigation Report.

It is recommended that this TM be forwarded to the regulatory agencies for their information, possibly in conjunction with your letter on the Air National Guard Readiness Center's (ANGRC's) intent to conduct a time-critical removal action under the National Contingency Plan. Hopefully, this TM will also satisfy your requirement for a report to provide to ANGRC legal counsel. If not, please let me know how it may be amended to do so.

If you have any questions, please do not hesitate to call Carl at 615-435-3406 or Bret at 615-435-3291.

Sincerely,



M. C. Wheeler, Program Manager
Hazardous Waste Remedial Actions Program



B. T. Sullivan, Project Manager
Hazardous Waste Remedial Actions Program

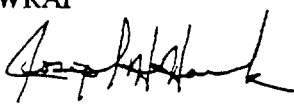
MCW:BTS:dmd

Attachments

cc: L. A. Baker (ASG)
J. Hawk (ASI)
File-RC-0326

MEMORANDUM

TO: Bret Sullivan, HAZWRAP

FROM: Joseph Hawk, ASI 

DATE: March 5, 1993

SUBJECT: Technical Memorandum for the FS-12 Free Product Investigation (HAZWRAP comments incorporated)

Enclosed, please find three(3) copies of the Technical Memorandum for the FS-12 Free Product Investigation at the Massachusetts Military Reservation on Cape Cod, Massachusetts. Your comments, transmitted via fax on March 3, 1993 and March 4, 1993, have been incorporated into the document. As you requested, an electronic copy of the text will be forwarded to you some time this afternoon.

If you have any questions or require additional information, please feel free to contact me at (615) 483-1274.

cc: Don Hudson
Tom Mattis
Suzanne McGinley
Mike Miracle
Project Files 9750.K-04.03.09.D

TECHNICAL MEMORANDUM
FS-12 FREE PRODUCT INVESTIGATION
MASSACHUSETTS MILITARY RESERVATION
MARCH, 1993

INTRODUCTION

Advanced Sciences, Inc. (ASI) was requested by the Hazardous Waste Remedial Action Program (HAZWRAP) to assume the lead role in responding to the discovery of free product in two water table wells during the Sandwich Remedial Investigation (RI). Free product was detected in water table wells WT-11 and WT-13 on December 7, 1992 and December 8, 1992, respectively, during the first Fall shift of the Sandwich RI. The samples of free product obtained from wells WT-11 and WT-13 were analyzed in December, 1992 by the Weston on-site field laboratory, the Brooks Air Force laboratory, and the United States Coast Guard Oil Identification laboratory. The laboratory analyses revealed constituents typical of aviation gasoline and jet fuel. A response action was initiated by the National Guard Bureau, and will be completed in a timely manner, so as to mitigate or eliminate the potential threat to human health and the environment, as per the requirements of the National Contingency Plan, 40 CFR 300.415(b)(3).

Phase I of the response consisted of defining the extent of free product. Results of the Phase I activities are discussed in subsequent sections of this technical memorandum. Remaining phases of this project will consist of estimating the recoverable and residual volumes of product through computer modelling, developing and implementing an effective remediation system(s), and providing technical support to the Base during installation and implementation of the remediation system(s).

DESCRIPTION OF FIELD ACTIVITIES

Field activities were conducted from January 12, 1993 through February 18, 1993 by personnel from ASI and Oak Ridge National Laboratory. Phase I of the free product investigation consisted of the installation of nine 3/4inch polyvinyl chloride (PVC) wells screened at the water table in order to define the extent of free product, as shown on Figure 1. All wells were constructed in accordance with the requirements stipulated in the Addendum to the Sandwich Investigation RI/FS Work Plan, dated January 1993, and any approved field changes. The well locations were chosen based on the location of an existing fuel transfer pipe in the area, suspected groundwater gradient, and results from previous sampling of existing water table wells in the area. Well locations originally depicted in the work plan addendum were modified as required as the field effort progressed based on results that verified the actual location of the free product.

After completion of each well, hydraulic conditions were allowed to stabilize for at least 12 hours before water table levels and/or product thicknesses were measured. Product gauging paste was used to determine the thickness of free product in each well. The paste is designed to change color upon contact with the product. The accuracy of the gauging paste was verified on January 21, 1993 by comparing interface probe data from well WT-13 with data obtained from using the gauging paste. The product thicknesses determined from each method were approximately the same. Product thicknesses and water level measurements for each 3/4inch PVC well, in addition to previously installed 2inch PVC water table wells in the vicinity of the free product study area, are documented in Table 1.

SUMMARY OF RESULTS

Based on free product thicknesses shown in Table 1, the maximum areal extent of free product is approximated to be 7.8 acres (Figure 1). Apparent product thicknesses measured in the 3/4 inch PVC wells and 2 inch PVC wells indicate minor true thicknesses of floating product most likely exist on top of the water table; however this will be verified during the computer modelling phase of the response, discussed in the following section.

SUBSEQUENT RESPONSE PHASES

Based on results of the field effort designed to evaluate the extent of free product, computer modelling will be performed to determine hydrocarbon spill volume and volume of product floating on the water table. The computer program SPILLCAD, developed by Environmental System & Technologies, Inc., will be used to evaluate recoverable and residual product volumes based on information obtained during the field effort conducted from January 12, 1993 through February 18, 1993, as well as regional aquifer characteristics (porosity, hydraulic conductivity, specific yield, etc.) obtained through a literature review of previous aquifer studies. SPILLCAD will be used to evaluate various free product recovery scheme (product-only pumping, multiple product/water pumping) to determine the effectiveness of each recovery system. Determination of the volume of residual product (product adsorbed to the soil matrix that can not be recovered through pumping systems) will permit accurate design of a system to remediate contaminated soil at the vadose zone/saturated zone interface.

Based on the thicknesses of floating product detected, a series of automated pumping systems might not be effective in recovering free product on top of the water table. Filter canisters, as discussed in Environmental Protection Agency Publication EPA-510-B-92-002, dated November 1992, could provide a cost effective means of determining recharge behavior of the free product. If recharge is relatively quick, the filter canisters could be used in parallel with a soil remediation system (vapor extraction, air sparging, bioremediation) installed at the vadose zone/saturated zone interface to effectively remediate the site.

Once the conditions at the vadose zone/saturated zone interface are sufficiently defined through the modelling effort, an effective remediation system will be developed. Plans and specifications for the furnishment and installation of the remediation system will be prepared based on modelling results, as well as performance standards stipulated by applicable federal, state, and local regulatory agencies. Technical support will be provided to the Base during installation and operation of the remediation system to ensure that all technical requirements specified in the contract are being satisfied.

Figure 2 presents a draft schedule for all phases of the FS-12 free product investigation.

TABLE 1

WATER LEVELS / PRODUCT THICKNESS

Page 1 of 2

Well Designation	Date of Measurement							
	1-21-93	1-23-93	1-25-93	1-26-93	1-28-93	2-4-93	2-5-93	2-7-93
LWA-1	WT-95.38' BGS P - 0.33' (paste)					WT-95.57' TOC FM P - .88'		
LWA-2				WT-94.58' BGS P - .21'		WT-94.33' TOC FM P - .12'		
LWA-3					WT-92.17' BGS P - 0 (rods)	WT-92.31' TOC FM P - .49'		
LWA-4						WT-95.37' BGS P - 0 (ORS)	WT-92.90' BGS P - .04'	
LWA-5								
LWA-6								
LWA-7								
LWA-9 (abandoned)		WT-97.16' BGS P - .20 (augers)						
LWA-10							WT-89.92' BGS P - 0	WT-89.90' BGS P - 0
LWA-11								
WT-3								
WT-6						WT-100.11' TOC (~2.7' stickup) P - 0		
WT-11				WT-92.03' TOC FM P - 0			WT-91.90' TOC FM P - 0	
WT-13	WT-98.18' TOC (~3.5' stickup) P - .63'			WT-98.04' TOC (~3.5' stickup) P - .48' (ORS)			WT-97.82' TOC (~3.5' stickup) P - .41'	
WT-15				WT-91.21' TOC FM P - 0				

WT - Water table, P - Product, BGS - Below Ground Surface, FM - Flush Mount, TOC - Top Of Casing

* - Reading may not be accurate

MMRFRM01

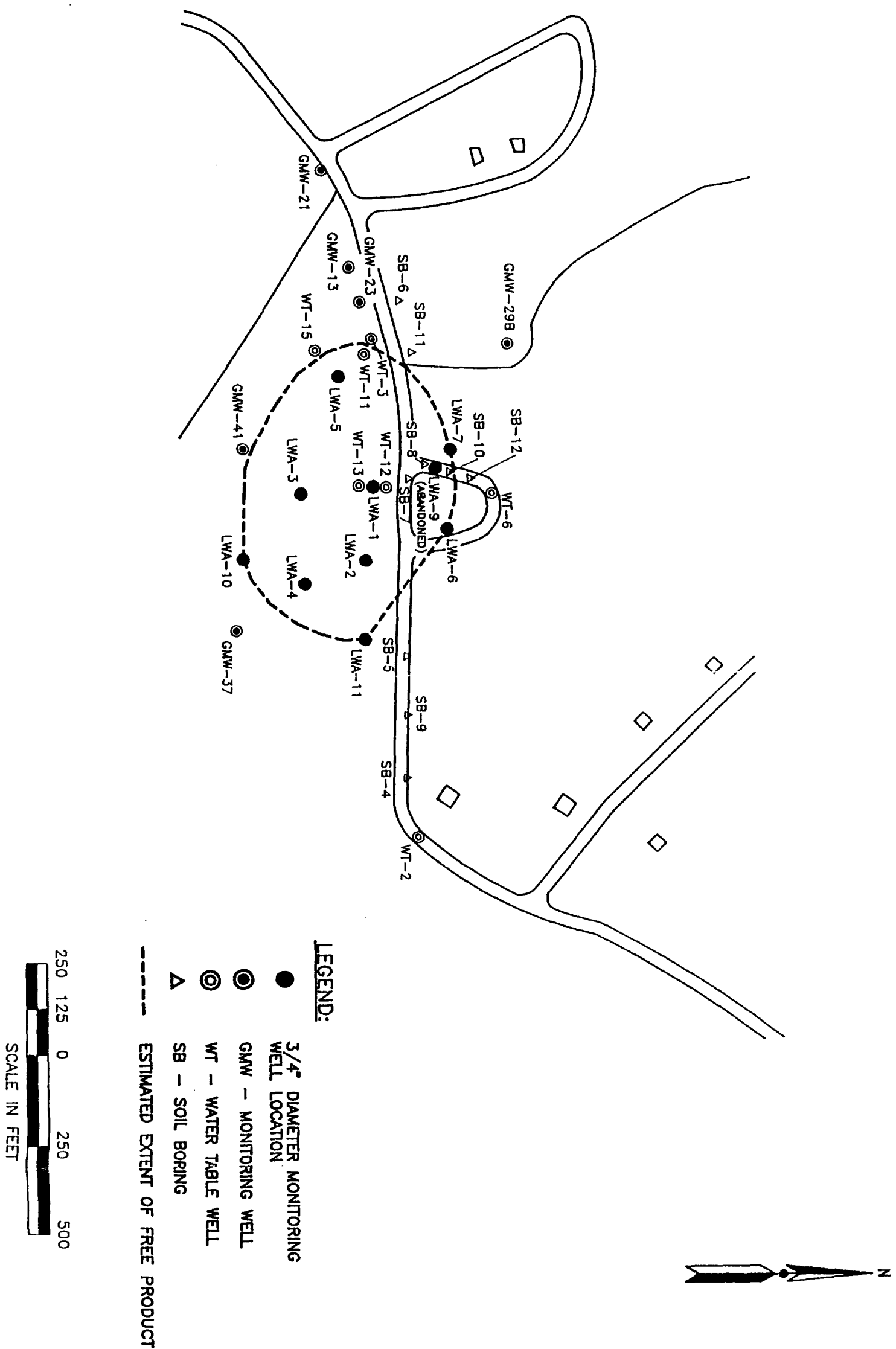
TABLE 1 (Continued)

WATER LEVELS / PRODUCT THICKNESS										Page 2 of 2
Well Designation	Date of Measurement									
	2-8-93	2-9-93	2-10-93	2-11-93	2-12-93	2-13-93	2-14-93	2-17-93		
LWA-1			WT-98.24' TOC FM P - .83'				WT-95.39' TOC FM P - .63'	WT-95.35' TOC FM P - .67'		
LWA-2				WT-94.16' BGS P - .08'			WT-94.13' TOC FM P - .10'	WT-94.11' TOC FM P - .03'		
LWA-3					WT-92.66' BGS P - .46'		WT-92.09' TOC FM P - .46'	WT-92.11' TOC FM P - .50'		
LWA-4			WT-93.12' BGS P - .06'				WT-92.70' BGS P - .06'			
LWA-5			WT-91.15' BGS	WT-91.35' BGS P - .42'			WT-91.18' BGS P-.04' (paste speckled)			
LWA-6				WT-96.67' BGS	WT-96.87' BGS P - 0		WT-96.55' BGS P - 0			
LWA-7					WT-96.99' BGS	WT-96.34' BGS P-.04' (paste speckled)	WT-95.84' TOC FM P - 0			
LWA-9 (abandoned)										
LWA-10		WT-86.05' BGS P - 0 *			WT-90.10' BGS P - 0		WT-89.79' BGS P - 0			
LWA-11	WT-96.40' BGS P - 0 (rods)	WT-92.44' BGS P - 0 *		WT-93.02' BGS P - 0			WT-92.81' BGS P - 0			
WT-3				WT-93.83' TOC (-2.2' stickup) P - 0						
WT-6										
WT-11			WT-91.85' TOC FM P - 0							
WT-13			WT-97.75' TOC (-3.5' stickup) P - .40'					WT-97.66' TOC (-3.5' stickup) P - .39'		
WT-15			WT-91.10' TOC FM P - 0	WT-91.12' BGS P - 0						

WT - Water Table, P - Product, BGS - Below Ground Surface, FM - Flush Mount, TOC - Top Of Casing

* - Reading may not be accurate

FIGURE 1.
MONITORING WELL LOCATIONS FOR DETERMINATION
OF FREE PRODUCT EXTENT



APPENDIX E

**Letter (with attachments) from M.C. Wheeler and B.T. Sullivan, HAZWRAP,
to Dan Santos, Martin Marietta Energy Systems, Subject: FS-12 Free
Product Recovery Modeling, dated May 18, 1993**

MARTIN MARIETTA ENERGY SYSTEMS, INC.

POST OFFICE BOX 2003
OAK RIDGE, TENNESSEE 37831

May 18, 1993

Mr. Daniel Santos
Installation Restoration Program
197 Granville Avenue
Box 41
Otis Air National Guard Base, Massachusetts 02542-5028

Dear Mr. Santos:

FS-12 Free Product Recovery Modeling

Attached is a Technical Memorandum that presents the results of the free product modeling conducted as part of the removal action for the FS-12/Forestdale investigation. On your review and approval, it is recommended that this Technical Memorandum be forwarded to the regulatory agencies for their information.

Also attached is a revised schedule for the removal action. The revised schedule is based on one set of plans and specifications being prepared for both the free product removal and soil remediation. This approach will simplify procurement, contract administration, and scheduling, but delay the beginning of remedial activities. The original submittal date for the draft plans and specifications changed because of the unanticipated complexity of the modeling effort and the total system design. A key concern about the schedule is when the "clock starts" for the time-critical removal action. If the removal cannot be accomplished as time-critical, then it may be advisable to address source remediation as part of the Feasibility Study instead of going through two public review and comment periods.

A third attachment is a cost-benefit analysis of additional site investigation work to provide additional design information. This Technical Memorandum is provided for your concurrent review to facilitate our discussions next week during the 60% design review meeting.

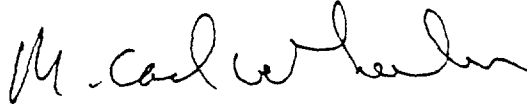
Mr. Dan Santos

2

May 18, 1993

We look forward to seeing you and Ed next week. Please call Carl at 615-435-3406 or Bret at 615-435-3291 if you have any questions.

Sincerely,



M. Carl Wheeler, Program/Project Manager
Hazardous Waste Remedial Actions Program



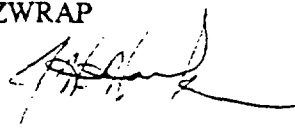
Bret T. Sullivan, Project Manager
Hazardous Waste Remedial Actions Program

BTS:MCW:dek

cc: L. A. Baker (ASG)
J. S. Bauman
J. Hawk (ASI)
File-RC-0326

MEMORANDUM

TO: Bret Sullivan, HAZWRAP

FROM: Joseph Hawk, ASI 

DATE: May 7, 1993

SUBJECT: FS-12 Free Product Recovery Modeling

Please find attached five(5) copies of the Technical Memorandum for the FS-12 Free Product Recovery Modeling. HAZWRAP review comments received on April 30, 1993 have been incorporated into the document.

If you have any questions or require additional information, please feel free to call me.

cc: Don Hudson
Tom Mattis
Thomas Goode
Roy Hoekstra
Alauddin Khan
John McDowell
Project Files 9750.K-04.03.09.D

Technical Memorandum
FS-12 Free Product Recovery Modeling
Massachusetts Military Reservation
May 1993

INTRODUCTION

Advanced Sciences, Inc. (ASI) was requested by the Hazardous Waste Remedial Action Program (HAZWRAP) to assume the lead role in responding to the discovery of free product in two water table wells during the Sandwich Remedial Investigation (RI). Phase I of this activity was to define the extent of the free product. This effort was completed during January 12, 1993 to February 18, 1993. The next phase of this activity is to model the free product and to develop an efficient pumping scheme to remove as much of the free product as possible.

DESCRIPTION OF MODELING SOFTWARE

The software packages of SPILLCAD and ARMOS-Lite as developed by Environmental Systems and Technologies, Inc. (ES&T) will be used as the model for this problem. The following is a brief description of these models.

SPILLCAD: SPILLCAD was developed by ES&T as a part of its Integrated Site Assessment and Remediation Support (ISARS) Project, aimed at the development of integrated modeling and database systems for hydrocarbon spill site assessment and remediation. The heart of the SPILLCAD is a relational database that enables site data to be viewed on CAD-generated (.DXF format) site maps; facilitating storage, retrieval, and graphical representation of data from monitoring wells and soil borings. Overlays of well and sampling locations, contoured fluid level data, dissolved concentrations, and soil concentrations may be viewed on the site map at any scale. Time series of fluid level and concentration data may be plotted on this map.

SPILLCAD can be used to determine hydrocarbon spill volume and the volume of free product floating on a water table. It can be also used to estimate soil and fluid properties required to carry out the calculations using a number of options. SPILLCAD is used to evaluate recoverable and residual product volumes and options to control free product migration, and to design free product recovery systems. This program can evaluate effects of multiple water pumping, or recharge wells, on oil flow interactively to design hydraulic control and free product recovery systems. Graphical representation of the recovery analyses during an interactive session enables one to evaluate a large number of options very quickly to maximize recovery or minimize water pumping as dictated by treatment cost and cleanup criteria.

SPILLCAD can interface with ARMOS-Lite. ARMOS-Lite is a two dimensional finite element model based on vertically integrated governing flow equations under an assumption of near equilibrium conditions in the vertical direction. ARMOS-Lite is capable of simulating the migration of light hydrocarbons in a homogenous unconfined aquifer. It can also simulate recovery of hydrocarbon using a network of recovery wells to facilitate design of remediation schemes.

DESCRIPTION OF MODELING ACTIVITIES

The first step of the modeling activities was to collect the existing water level data and the product thickness data. The product thickness data collected during the January - February field effort were used in the modeling. An estimated extent of free product based on this data is shown in Figure 1. The measured apparent thicknesses of free product in the well are also listed in this figure. The water level data collected on March, 15, 1993 were used for the modeling. From the existing surveys on water table wells elevations were calculated for the LWA wells. All of the existing data were then entered into the SPILLCAD program and the model was run to see how the program would respond with the existing data. In the original runs some of the outlying wells were used in the model to help establish a regional ground water flow pattern. The model divides the region under consideration into grids and then uses the well data to calculate the gradient and area of the floating product. By using only the existing well locations, the model did not have enough information to properly represent the free product and extended the free product beyond the actual locations. Wells PP-1 through PP-5 (Figure 2) were added to the model to help calibrate the model and have the calculated free product match the actual extent. Also, the domain of the model was made smaller and the model was used with more elements to improve the calibration. The ground water gradient was calibrated by the addition of eight wells X-1 through X-8 (Figure 2) beyond the boundary of the specified model domain. Figure 2 shows the simulated thickness of free product in the well. Simulated water table elevation (gradients) are also shown in this figure.

SOIL AND FLUID PROPERTIES

A large number of factors affect the efficiency of free product recovery operations. These include soil permeability and capillary characteristics, hydrocarbon properties, natural hydrologic conditions, spill size and duration, location and operating conditions of recovery wells, and the time lapse between spill detection and initiation of recovery operations. The numerical models SPILLCAD and ARMOS-Lite are capable of taking into consideration all these factors and their complex interactions. The simulation results are dependent on the selection and/or estimation of these factors. The physical parameters used by these models are presented in Table 1. Of the soil properties listed in Table 1, only hydraulic conductivity, porosity, and specific yield are based on field data (obtained from literature search), while the remaining properties or parameters are estimated by SPILLCAD using these field data. All the fluid properties are the default values for diesel fuel used by the program SPILLCAD (ES&T 1993). Analysis of the free product samples (Weston, 1992) indicates close resemblance with diesel fuel as compared to gasoline. Therefore, parameters/properties of diesel fuel were used in this modeling.

Sensitivity runs were performed using SPILLCAD by varying the most sensitive parameters individually to evaluate the impact on the estimation of total oil volume and the total recoverable product. The results of this analysis are presented in Table 2. As can be seen from this table, the prediction of total oil volume varies from 4,400 to 71,000 gallons with variation of α from 4.5 to 23.7, 57,500 to 85,000 gallons with variation of n from 2.0 to 5.0, and 52,000 to 93,000 gallons with change of free product type from fuel oil #2 to gasoline, respectively. With the variation of hydraulic conductivity, the estimate of total oil volume does not change, but there is a significant change in the estimate of total free product recoverable volume.

WELL	PRODUCT THICKNESS (FEET)	DATE
LWA-1	0.67	2-17-93
LWA-2	0.10	2-14-93
LWA-3	0.50	2-17-93
LWA-4	0.06	2-14-93
LWA-5	0.42	2-11-93
LWA-6	0	2-14-93
LWA-7	0	2-14-93
LWA-10	0	2-14-93
LWA-11	0	2-14-93
WT-3	0	2-11-93
WT-6	0	2-4-93
WT-11	0	2-5-93
WT-13	0.41	2-5-93
WT-15	0	2-11-93

FIGURE 1. MONITORING WELL LOCATIONS FOR DETERMINATION OF FREE PRODUCT EXTENT

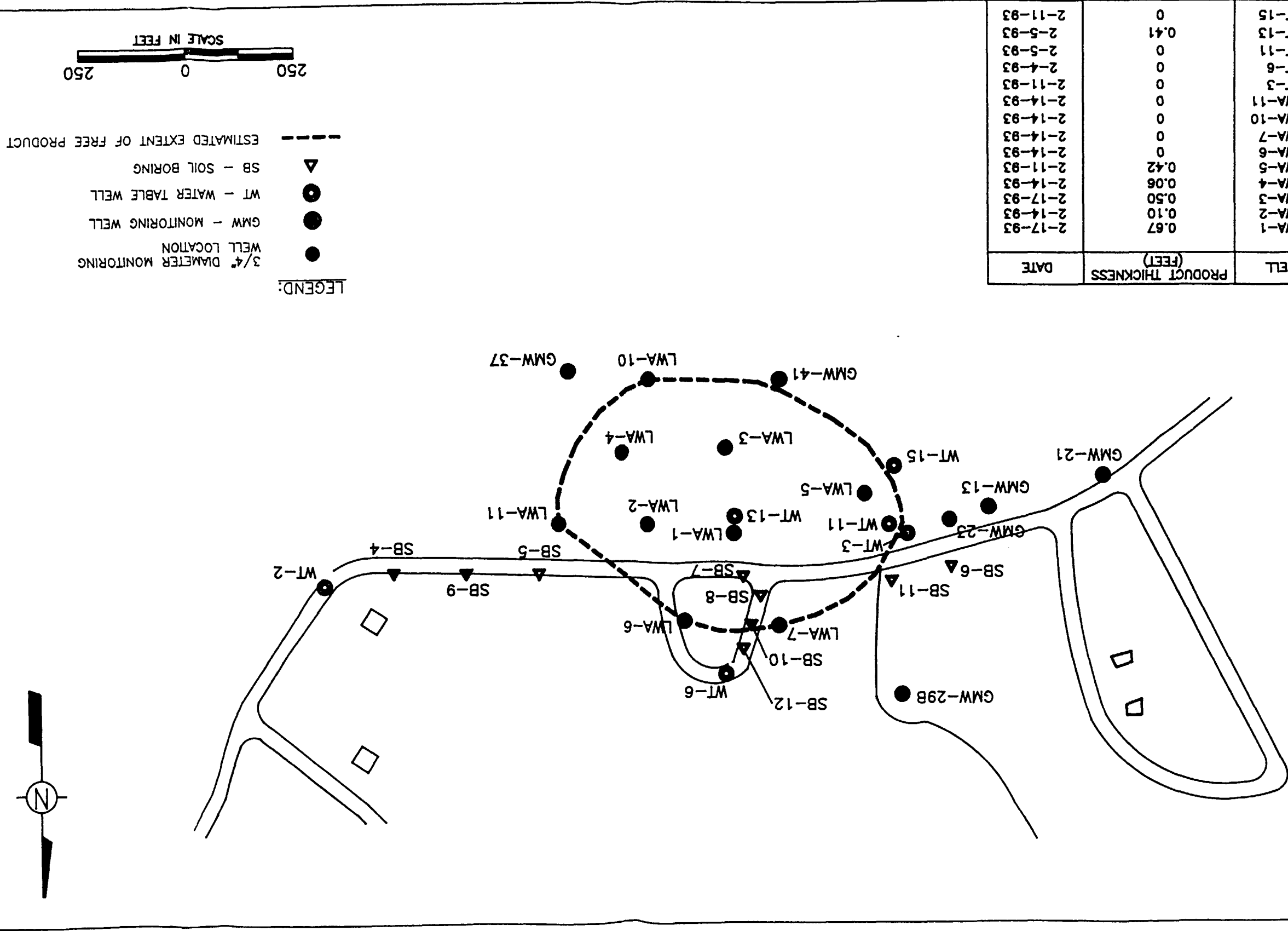


FIGURE 2. INITIAL CONDITIONS AFTER CALIBRATION

TABLE 1

**PARAMETERS USED BY THE MODELS FOR ESTIMATION OF FREE OIL VOLUME
AND RECOVERABLE PRODUCT FROM WELL FLUID LEVEL DATA**

SOIL PROPERTIES	
Saturated Hydraulic Conductivity, K_{sw} (ft/day)	250 ¹
Total Porosity, ϕ	0.39 ^{2,3}
Specific Yield, S_y	0.30 ³
VG Mean Pore Size Parameter, α (ft ⁻¹)	23.7 ⁴
VG Pore Size Distribution Exponent, n	2.7 ⁵
Water Saturation at Field Capacity, S_m	0.23 ⁶
Maximum Unsaturated Zone Residual Oil Saturation, S_{og}	0.053 ⁷
Maximum Saturated Zone residual Oil Saturation, S_{or}	0.231 ⁸
FLUID PROPERTIES ⁴	
Ratio of Oil to Water Density, ρ_{ro}	0.83
Ratio of Oil to Water Viscosity, μ_{ro}	2.3
Ratio of Water Surface Tension to Oil Surface Tension, β_{wo}	3.0
Ratio of Water Surface Tension to Oil-Water Interfacial Tension, β_{ow}	1.5

VG indicates Van Genuchten Model

¹ Represents a geometric mean of literature values (Reference: Whitman and Howard, Inc. 1992; Guswa & Londquist 1976; E.C. Jordan Co. 1988; LeBlanc 1982 & 1984; Garabedian 1987; and Hess 1988)

² Reference: ASI, 1992

³ Reference: Morris and Johnson 1967

⁴ Reference: ES&T 1992

⁵ Estimated value ($\alpha = A * K_{sw}$; Reference: ES&T 1993)

⁶ Estimated value ($S_m = S_y / \phi$; Reference: ES&T 1992)

⁷ Estimated value ($S_{og} = f_{og} S_m (1 - S_m)$; Reference: ES&T 1992)

⁸ Estimated value ($S_{or} = f_{or} (1 - S_m)$; Reference: ES&T 1992)

TABLE 2

**ESTIMATION OF FREE OIL VOLUME AND RECOVERABLE PRODUCT
FROM WELL FLUID LEVEL DATA: SENSITIVITY TO THE PARAMETERS**

Scenario 1:	
Saturated Hydraulic Conductivity, K_{sw} (ft/day)	250
VG Mean Pore Size parameter α , (ft ⁻¹)	23.7
VG Pore Size Distribution Exponent, n (dimensionless)	2.7
Type of Free Product	Diesel Fuel
TOTAL VOLUME = 71,000 gallons; Total recoverable Volume = 18,000 gallons	

Scenario 2	
Saturated Hydraulic Conductivity, K_{sw} (ft/day)	250
VG Mean Pore Size parameter α , (ft ⁻¹)	4.5
VG Pore Size Distribution Exponent, n (dimensionless)	2.7
Type of Free Product	Diesel Fuel
TOTAL VOLUME = 4,400 gallons; Total recoverable Volume = 2,100 gallons	

Scenario 3	
Saturated Hydraulic Conductivity, K_{sw} (ft/day)	250
VG Mean Pore Size parameter α , (ft ⁻¹)	9.0
VG Pore Size Distribution Exponent, n (dimensionless)	2.7
Type of Free Product	Diesel Fuel
TOTAL VOLUME = 19,800 gallons; Total recoverable Volume = 1,000 gallons	

Scenario 4	
Saturated Hydraulic Conductivity, K_{sw} (ft/day)	250
VG Mean Pore Size parameter α , (ft ⁻¹)	18.0
VG Pore Size Distribution Exponent, n (dimensionless)	2.7
Type of Free Product	Diesel Fuel
TOTAL VOLUME = 54,000 gallons; Total recoverable Volume = 9,000 gallons	

TABLE 2 (continued)

Scenario 5	
Saturated Hydraulic Conductivity, K_{sw} (ft/day)	250
VG Mean Pore Size parameter α , (ft ⁻¹)	23.7
VG Pore Size Distribution Exponent, n (dimensionless)	2.0
Type of Free Product	Diesel Fuel
TOTAL VOLUME = 57,500 gallons; Total recoverable Volume = 11,000 gallons	

Scenario 6	
Saturated Hydraulic Conductivity, K_{sw} (ft/day)	250
VG Mean Pore Size parameter α , (ft ⁻¹)	23.7
VG Pore Size Distribution Exponent, n (dimensionless)	5.0
Type of Free Product	Diesel Fuel
TOTAL VOLUME = 85,000 gallons; Total recoverable Volume = 28,000 gallons	

Scenario 7	
Saturated Hydraulic Conductivity, K_{sw} (ft/day)	160
VG Mean Pore Size parameter α , (ft ⁻¹)	23.7
VG Pore Size Distribution Exponent, n (dimensionless)	2.7
Type of Free Product	Diesel Fuel
TOTAL VOLUME = 71,000 gallons; Total recoverable Volume = 12,000 gallons	

Scenario 8	
Saturated Hydraulic Conductivity, K_{sw} (ft/day)	380
VG Mean Pore Size parameter α , (ft ⁻¹)	23.7
VG Pore Size Distribution Exponent, n (dimensionless)	2.7
Type of Free Product	Diesel Fuel
TOTAL VOLUME = 71,000 gallons; Total recoverable Volume = 27,500 gallons	

TABLE 2 (continued)

Scenario 9	
Saturated Hydraulic Conductivity, K_{sw} (ft/day)	250
VG Mean Pore Size parameter α , (ft ⁻¹)	23.7
VG Pore Size Distribution Exponent, n (dimensionless)	2.7
Type of Free Product	Gasoline
TOTAL VOLUME = 93,600 gallons; Total recoverable Volume = 37,000 gallons	

Scenario 10	
Saturated Hydraulic Conductivity, K_{sw} (ft/day)	250
VG Mean Pore Size parameter α , (ft ⁻¹)	23.7
VG Pore Size Distribution Exponent, n (dimensionless)	2.7
Type of Free Product	Fuel Oil #2
TOTAL VOLUME = 52,000 gallons; Total recoverable Volume = 1,600 gallons	

Shading in each scenario represents the parameter that was varied in the model run.
 VG indicates Van Genuchten Model

MODEL APPLICATION AND RESULTS

After the selection of the model parameters, ARMOS-Lite was used to optimize the well placement and well operating conditions. SPILLCAD was used to demonstrate the capture zone (Figure 3) for each of the pumping scenarios. Product recovered versus days of pumping were plotted (shown in Figure 4) to identify the optimum scenario. It was observed that maximum recovery could be obtained by pumping with eight wells with the locations shown in Figure 3. Therefore, this scenario was chosen to optimize the pumping rates using ARMOS-Lite. Figure 5 shows cumulative recovery versus time for different water pumping rates. A plot of recovery versus water pumping rates (Figure 6) indicates an optimum rate for this well placement occurs at about 320 gpm (40 gpm per well) yielding recovery of 34,000 gallons (48 % of the estimated total volume).

UNCERTAINTY IN THE MODELING RESULTS

The major uncertainty in the analysis is the estimation of model parameters when data were not available. The certainty in the modeling results can be significantly improved by calibrating the model with field data. The most critical parameter in this simulation the data of which is lacking is α . The uncertainty in the modeling results can be significantly reduced by calibrating α with field data. This can be done by designing the product recovery system in stages, i.e., by installing the system based on present modeling results to be operated for a short period of time (10 to 15 days). The product recovery data to be obtained from this short period of operation can be used to calibrate the model. The simulation results from the calibrated model should then be used for adjusting the final pumping rates (i.e., long term recovery plan).

FIGURE 3. DIFFERENTIAL GRADIENT AFTER PUMPING FOR THE 8 WELLS @ 40 GPM

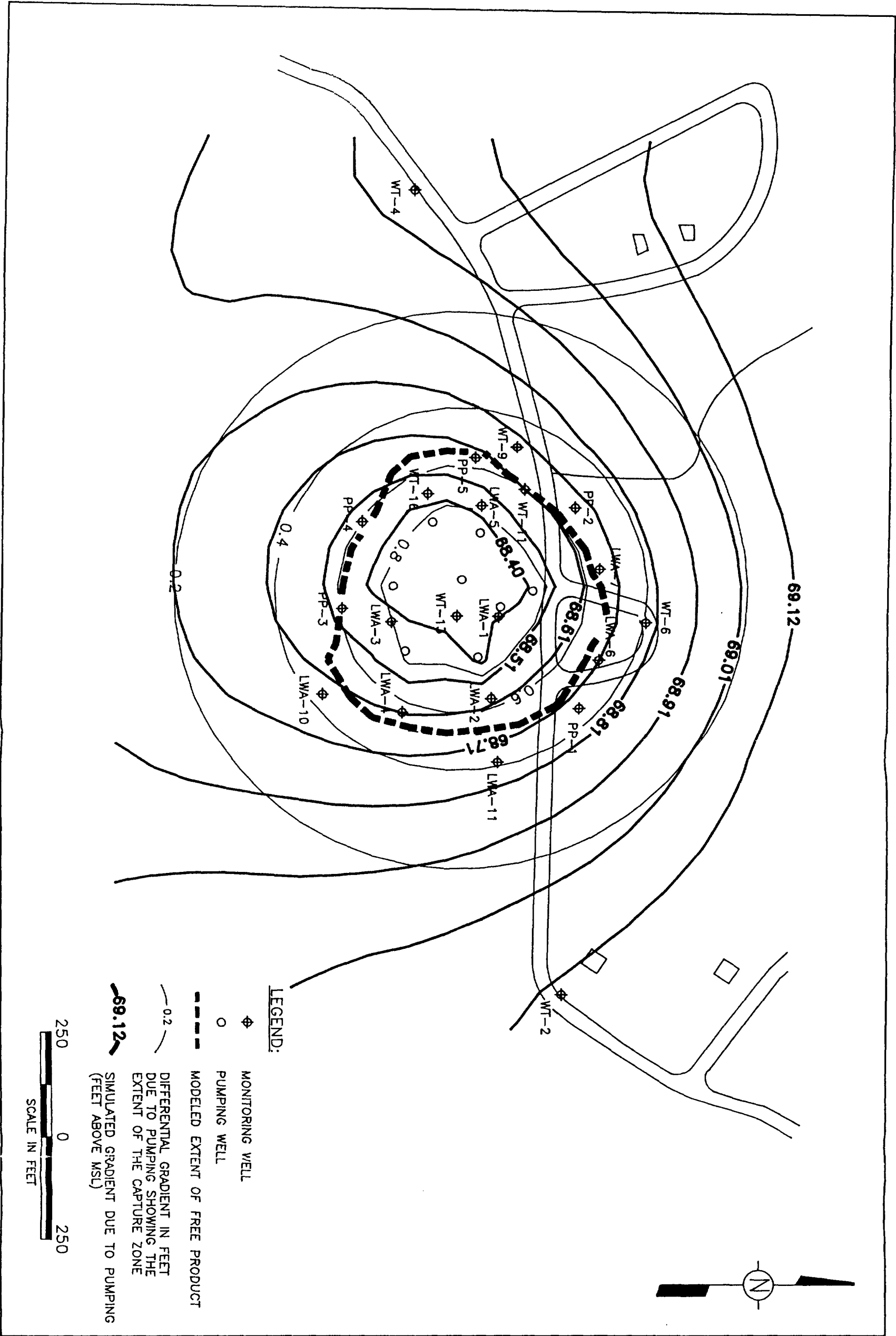


Figure 4. Product Recovery - Varying Number of Wells

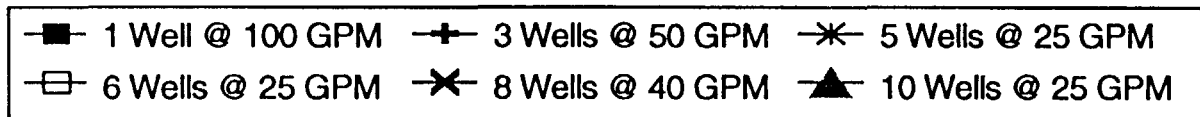
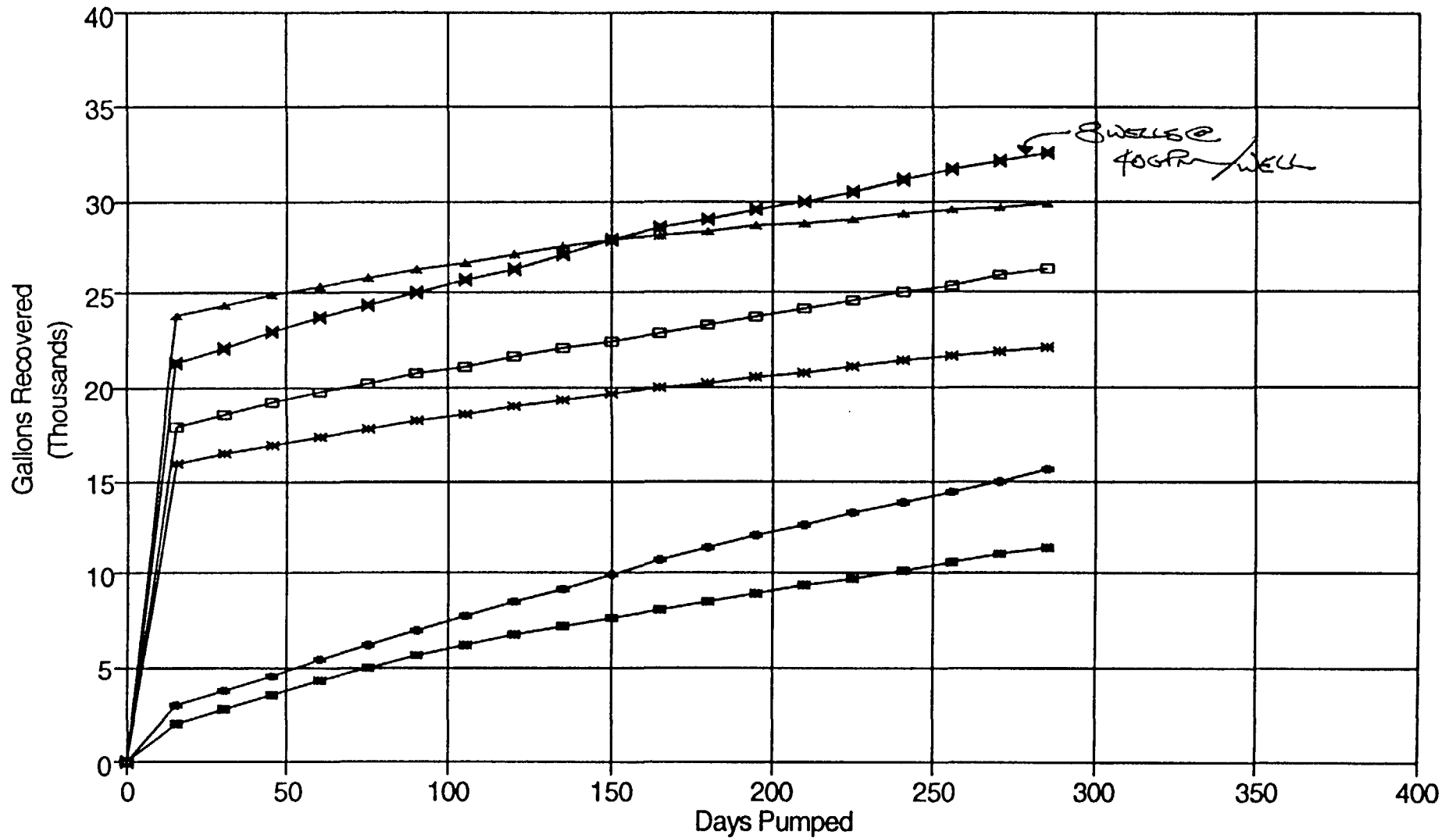


Figure 5. Product Recovery 8 Wells
With Varying Pumping Rates

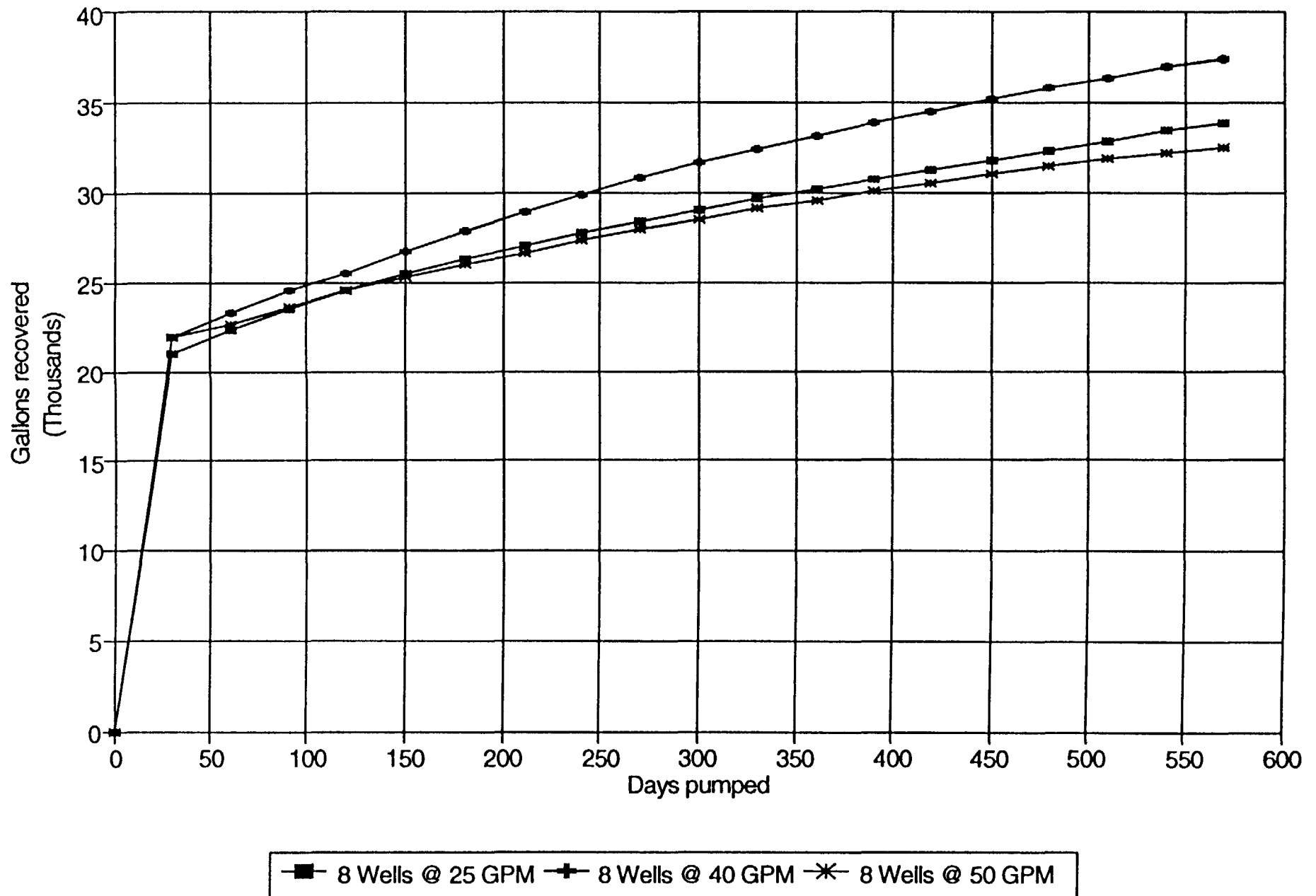
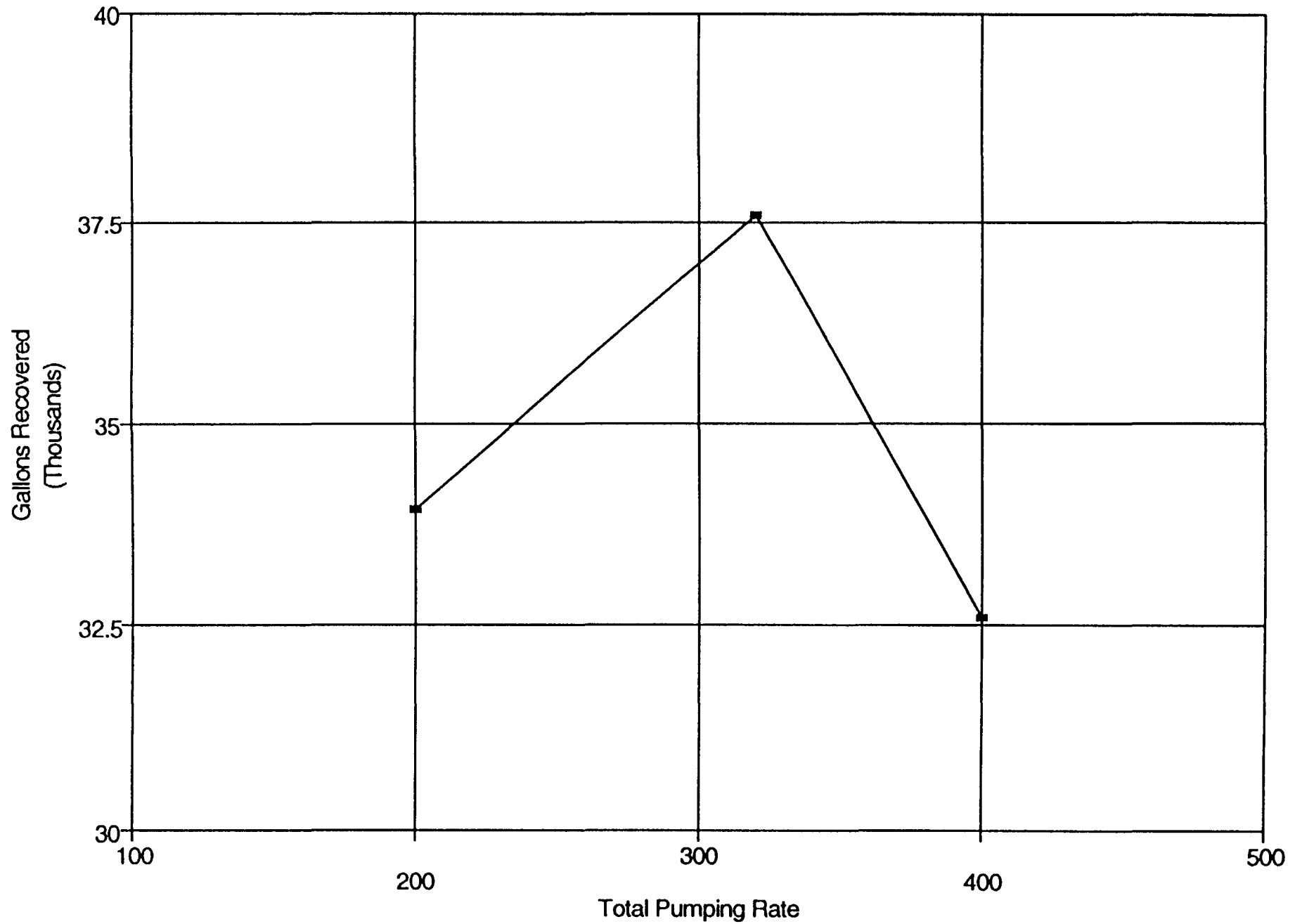


Figure 6. Recovery Vs. Pumping Rate



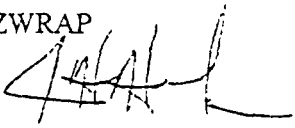
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APPENDIX F

**Memorandum from Joe Hawk, Commodore Advanced Sciences, Inc.,
to Carl Wheeler, HAZWRAP, Subject: Flow Rate Measurement Throughout
Soil Vapor Extraction Well Field and Off-Gas Treatment System,
dated July 8, 1996**

MEMORANDUM

TO: Carl Wheeler, HAZWRAP
FROM: Joseph Hawk, ASI 
DATE: July 8, 1996
SUBJECT: Flow rate measurements throughout soil venting well field and off-gas treatment system (Subcontract No. 77K-FJM97C)

During the week of June 10-14, 1996, John McDowell and I visited the MMR FS-12 site to evaluate actual source area remediation system operating conditions, and to evaluate and address other miscellaneous operational concerns of the EPA, MADEP, and IRP office. The purpose of this memorandum is to discuss flow rate measurements obtained throughout the soil venting well field and off-gas treatment system and provide recommendations and justification for additional flow rate measurements. A separate memorandum will be prepared that addresses miscellaneous operational concerns and other information obtained during the trip.

Air flow velocities were measured in soil venting wells SV-1 through SV-21 and the following locations throughout the off-gas treatment system:

- south field manifold prior to main header (8-in. diameter pipe)
- north field manifold prior to main header (8-in. diameter pipe)
- main manifold before air/water separator (12-in. diameter pipe)
- after heat exchanger in 18-in. diameter vertical piping

Air velocities measured in soil venting wells SV-1 through SV-21 are shown in Table 1. Flow rates, also shown in Table 1, were determined by multiplying velocities by the cross sectional area of a 4-in. diameter pipe ($A = 0.087$ sq. ft.). The sum of flow rates measured in each soil venting well is 3,947 acfm. The combined flow rate measured in the north and south field manifolds (assuming air velocity in the south field manifold is 6,000 ft/min and air velocity in the north field manifold is 4,900 ft/min) was 3,804 acfm. The flow rate measured in the main manifold before the air/water separator was approximately 3,925 acfm (assuming air velocity is 5,000 ft/min). The flow rate measured in the 18-in. diameter vertical piping after the heat exchanger was approximately 3,358 acfm (assuming air velocity is 1,900 ft/min). This indicates that a certain volume of the treated air out of the catalytic oxidation unit is being lost out of the heat exchanger before being treated by the vapor-phase carbon unit.

The results correlate well; however, since the system was originally designed to achieve a flow rate of 3,500 scfm, and the air flow measuring station transmits a flow rate of approximately 2,500 acfm to the system computer, the following observations are made:

- The ULTRAC airflow measuring station is installed immediately after a 45° elbow on the blower outlet side. Based on the system configuration and the manufacturer's recommendations for installation clearances (see attached vendor information), ASI feels the flow rate indicated via the computer system is low and does not accurately reflect the actual system flow rate.
- ASI feels the velocity meter used to measure velocities in the soil venting wells and off-gas treatment system is reading high (based on velocity probe reading of a vehicle travelling at 30 mph), indicating the system flow rates are being overestimated.

RECOMMENDATIONS

DGC, Inc. shall utilize experienced personnel to measure flow rates before and after the heat exchanger via EPA Method 1 specified in 40 CFR 60. Calculations shall be performed per EPA Method 2. ASI feels this method is required to more accurately determine the total system flow rate. Recommended locations of flow rate measurements via EPA Method 1 are shown on Figure 1. An accurate determination of total system flow rate is important to evaluate mass removal and to evaluate actual operating conditions versus design conditions. The following information shall be obtained during measurement of air velocities:

- velocity pressures in inches of water at each of 24 locations on each of 2 traverses at each location shown on Figure 1 (see Table 1-2 in EPA 40 CFR 60),
- duct static pressure during testing in inches of water,
- duct air temperature during testing, and
- barometric pressure during testing in inches of water (recommend calling the airport and asking for station pressure or calling the United States Weather Service).

ASI feels that a determination of flow rate after the heat exchanger is necessary to evaluate actual air loss after the catalytic oxidation unit and before the vapor-phase carbon unit.

If you have any questions or require additional information, please feel free to call me at (423)483-1274.

c: Ed Pesce, HQ AFCEE/MMR
 Bob Davis, HQ AFCEE/MMR
 John McDowell, ASI
 Project File 9043.1.1.20.20.C

Table 1

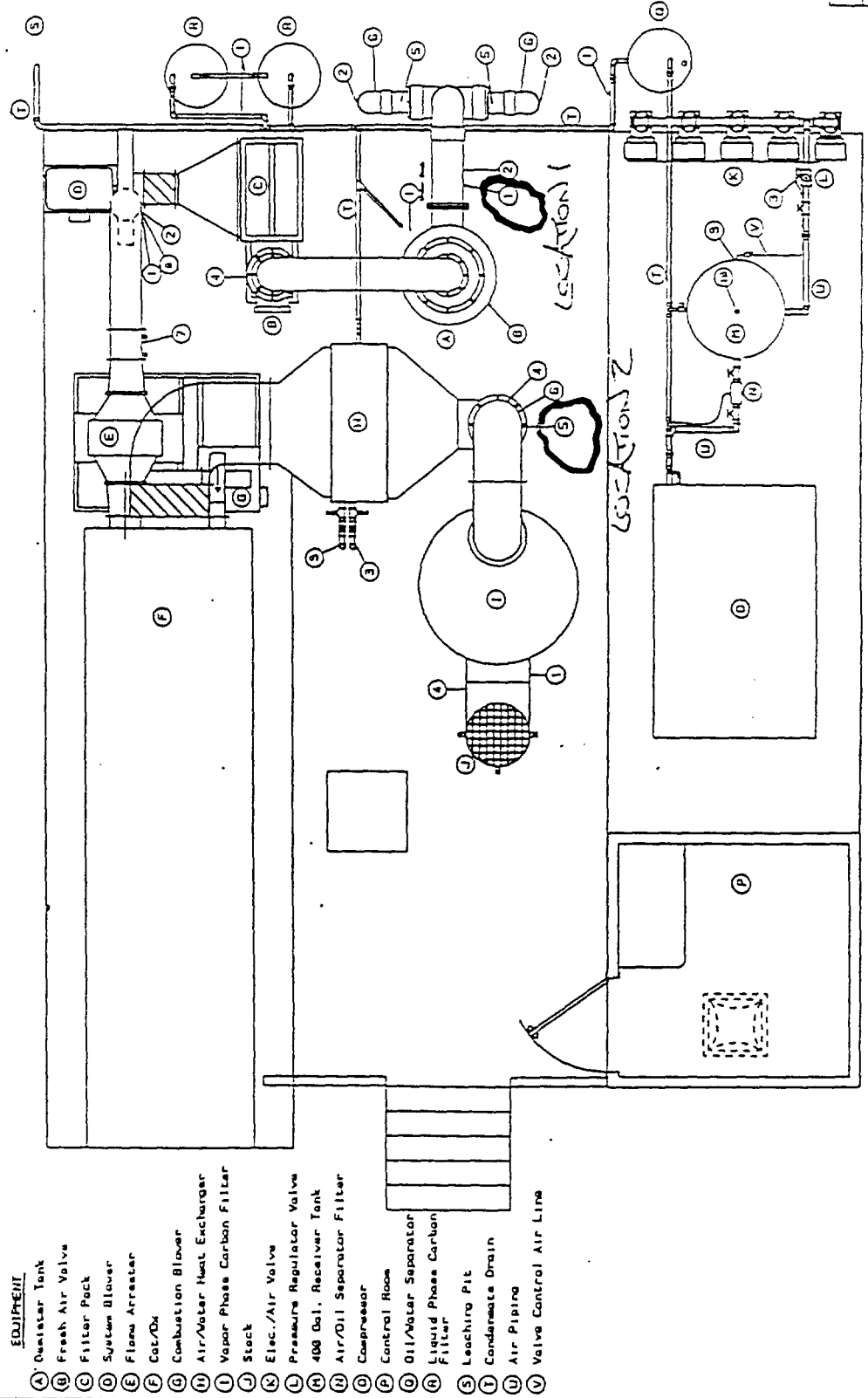
Well No.	Vacuum (inches of H ₂ O)	Velocity (ft/min)	Flow Rate (acfm)
SV-1	3.5	1900	165
SV-2	4.8	1700	148
SV-3	4.0	1600	139
SV-4	4.0	1800	157
SV-5	5.5	2400	209
SV-6	6.5	2500	218
SV-7	3.5	1600	139
SV-8	4.25	2100	183
SV-9	6.5	2700	235
SV-10	7.5	2800	244
SV-11	3.0	1300	113
SV-12	6.0	2800	244
SV-13	4.5	1900	165
SV-14	6.25	2800	244
SV-15	3.5	1750	152
SV-16	4.25	2600	226
SV-17	4.0	2200	191
SV-18	4.0	2500	218
SV-19	4.0	2100	183
SV-20	3.5	2100	183
SV-21	4.5	2200	191
Total			3,947

Note:

1. Well head velocities measured during the week of June 10-14, 1996

SENSORS and P.O.S.

- (1) Sample Port
- (2) Vacuum Gauge
- (3) Pressure Gauge
- (4) Hydrocarbon Monitor
- (5) Temperature Probe
- (6) Temperature Sensor
- (7) Air Flow Sensor
- (8) High Level Alarm
- (9) ICL Sensor
- (10) Pressure Relief Valve



EQUIPMENT

- (A) Reactor Tank
- (B) Fresh Air Valve
- (C) Filter Pack
- (D) System Blower
- (E) Flow Arrestor
- (F) Cat/Ox
- (G) Combustion Blower
- (H) Air/Water Heat Exchanger
- (I) Vapor Phase Carbon Filter
- (J) Stack
- (K) Elec./Air Valve
- (L) Pressure Regulator Valve
- (M) 400 Gal. Receiver Tank
- (N) Air/Oil Separator Filter
- (O) Compressor
- (P) Control Room
- (Q) Oil/Water Separator
- (R) Liquid Phase Carbon Filter
- (S) Leaching Pit
- (T) Condensate Drain
- (U) Air Piping
- (V) Valve Control Air Line

F/S 12 Site

0115 M/F, HASS.

Dave Birdner Contractor Inc.



Installation & Operation of ULTRAC Airflow Measuring Stations

UNPACKING & INSPECTION

Unpack the station carefully to avoid damaging the honeycomb, straightening-vane section. If any portion of the honeycomb is bent, it may be straightened using needle-nose pliers. Be sure to remove all cardboard protecting panels and packing materials from the unit. A careful visual inspection should reveal any shipping damage such as bent or broken measuring tubing, damaged casing, etc. If shipping damage is evident, the unit must be repaired prior to placing it in service to avoid inaccurate signals. For advice on repairs, consult your local ULTRATECH Industries, Inc. sales representative or the ULTRATECH Engineering Department at 1-800-556-2004.

INSTALLATION

ULTRAC stations in sizes up to 18 inches may be readily installed by positioning them in the duct opening and bolting them securely in place. Take care not to damage the honeycomb when positioning the unit between the flanges of the duct. Orient the unit with the honeycomb section facing upstream. Check the flow direction arrow on the side of the station. Install standard gaskets or apply sealant (suitable to the duct system) between the flanges to give a positive seal. Tighten the flange bolts securely, but do not over-tighten. Approximately 12 to 15 ft. lbs. torque is sufficient. Refer to the table "INSTALLATION CLEARANCES" on the next page for allowable distances from duct obstructions.

Larger stations may be lifted into position using a chain or cable sling placed around the perimeter of the station, or by attaching hooks or eyebolts to the flanges. Stations 60-inches or larger may require eyebolts installed in a center balanced area in the "top" of the unit. Note that the "top" may be any side of the station, depending on the desired location of the instrument connections. The ULTRAC station will function equally well regardless of the installation angle or the inclination of the duct. If eyebolts are installed, care must be taken when drilling into the casing to avoid damage to the honeycomb or measuring assembly. The use of 3/8" eyebolts is suggested, with a 4" x 4" washer inside to evenly distribute lifting stress. After installation of the unit, the eyebolt may be left in place or removed and the hole plugged with a short bolt, washer, and nut to prevent air leakage.

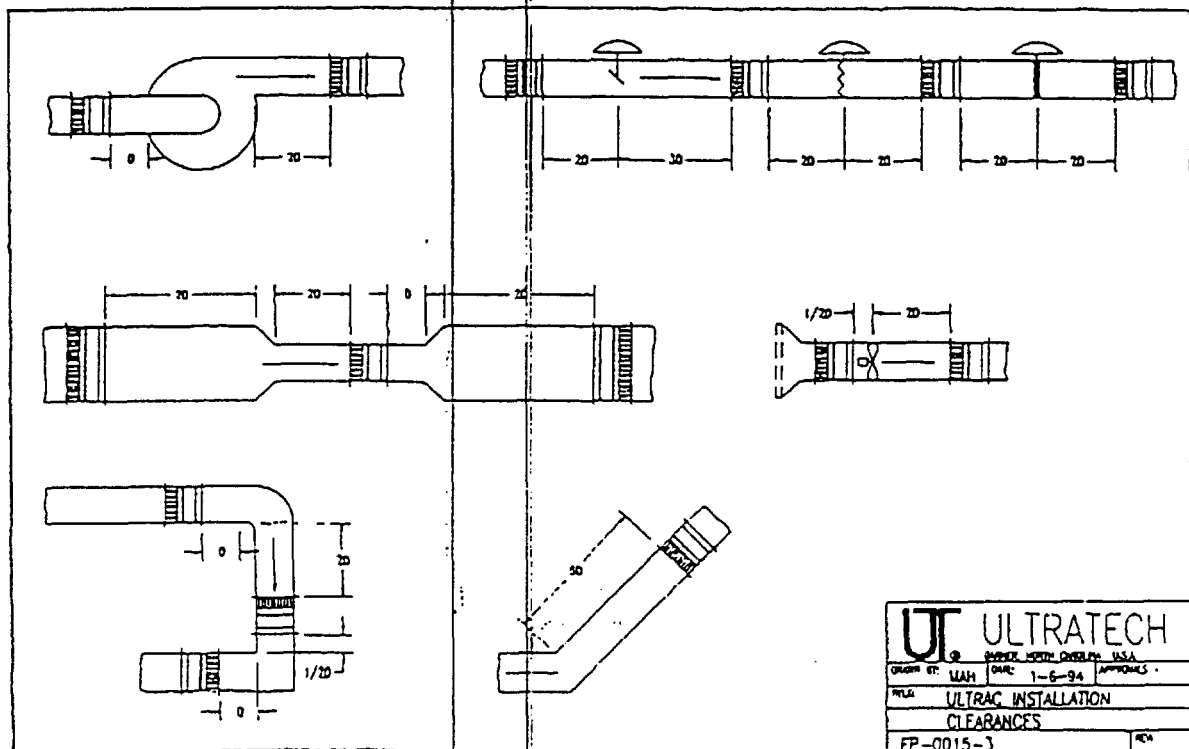
INSTRUMENT OR GAUGE CONNECTIONS

Connect the instrument tubing to the HI and LO station connections. The HI and LO ports are clearly labelled (HI is on the upstream side of the unit). Use two wrenches when installing the tubing fittings, taking care to hold the station fitting securely while tightening the tubing fitting. Avoid twisting the internal parts of the measuring assembly. Use thread sealer to prevent leaks, since small leaks may cause inaccuracies in measurements. ULTRAC units are furnished with and without manifold valves (zeroing valves), according to the specifications of the job. See specifications on the ULTRAC Zeroing Manifold Valve for details.

MODEL IDENTIFICATION

The model and serial number of each ULTRAC Airflow Metering Station is inscribed on the identification tag which is riveted to the casing adjacent to the instrument connections. The measuring area of the station (in square feet) is engraved directly on the casing next to this tag. The area information is necessary to establish actual C.F.M. (cubic feet per minute) flow values since the output signals from the station will be F.P.M. (feet per minute) velocity measurement as indicated by a pressure in inches of water column (in w.c.). F.P.M. equals C.F.M. divided by the area in square feet.

If any problem arises concerning the application, installation or use of this unit or any ULTRATECH product, please contact your local ULTRATECH sales representative or the ULTRATECH Industries, Inc. Engineering Department at 1-800-656-2004.



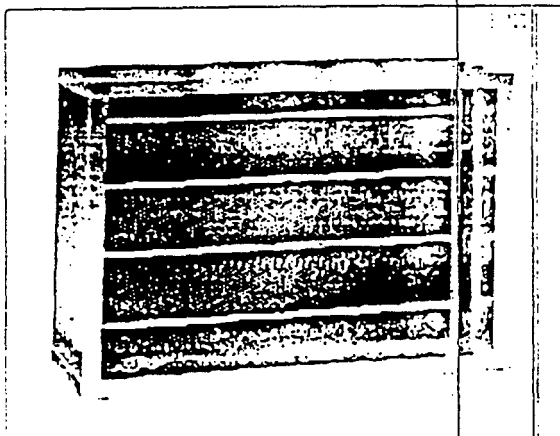
SPEC EP-0001-6



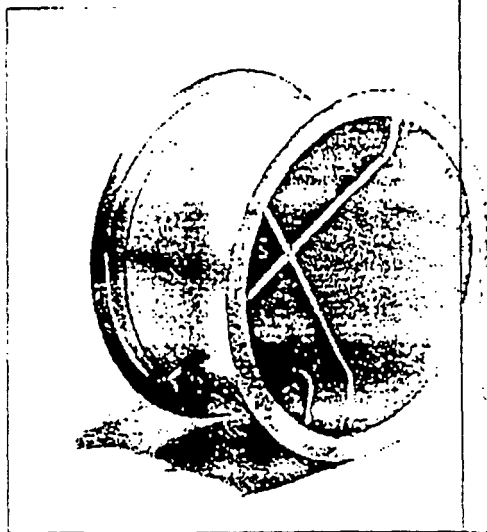
ULTRAC AMS *Airflow Measuring Stations*

APPLICATIONS

ULTRATECH ULTRAC Airflow Measuring Stations (AMS) provide accurate, repeatable measurement of air movement through ducts and piping. Lightweight, rugged construction coupled with ease of installation and economical pricing make these devices particularly applicable to the HVAC trade. Durable, quality construction ensures long-term, trouble-free operation. ULTRAC Airflow Measuring Stations are compatible with manometers, differential pressure gauges, and differential pressure transmitters used for airflow indication and control.



ULTRAC AMS 911



ULTRAC AMS 811

DESCRIPTION

ULTRAC Airflow Measuring Stations use multiple averaging Pitots to determine total velocity and static pressure measurements. The Pitot sensors are placed across the flow stream according to industry standards for equal-area averaging (the standard Pitot traverse). ULTRAC's unique AMS construction eliminates non-essential hardware that can cause build-up of dirt and foreign matter on the measuring assembly.

ULTRAC Airflow Measurement Stations are available in round, rectangular and oval configurations. All configurations feature a sensor assembly that allows for duct expansion and contraction. The 12-inch flanged steel casing has an aluminum, hexagon-celled straightening vane section that is mechanically fastened to the inlet. This eliminates turbulence and corrects flow direction, thereby increasing the velocity profile.

Various casing and sensor designs are available, as are most types of proprietary duct connecting systems. Please contact ULTRATECH about these options.

SUGGESTED SPECIFICATIONS

Airflow measuring stations shall be of the multiple averaging Pitot, static pressure sensor type, with all total pressure sensors distributed for equal-area averaging of flows. They shall be of unitary (spool-piece) construction, of not less than 16-gauge sheet steel with flanged duct connections. Flow-straightening vanes shall be incorporated into the structure. Internal Pitot and static sensor shall be constructed of copper to ASTM B88 standards. Instrument connections shall be 1/2" NPT Female. Mounting hardware shall not penetrate the sensor assembly.

The airflow measuring stations shall be ULTRACAMS, as manufactured by ULTRATECH INDUSTRIES, INC., Garner, NC, U.S.A.

SPECIFICATIONS FOR STANDARD UNITS

ACCURACY: $\pm 2\%$ to 6000 feet per minute
($\pm 0.5\%$ at 2000 feet per minute)
TEMPERATURE: Maximum operating 400°F
PRESSURE: Maximum operating, 6-in. w.c.
PRESSURE DROP: Less than 0.13 in. w.c.
at 2000 feet per minute with 3/8" cell
FLOW STRENGTHENING VANES: 3/8"
aluminum hexagon cell
MAXIMUM DESIGN FLOW: 6000 ft./min.
CASING: 16-gauge galvanized sheet metal
Length: 12-in. overall
PITOT AND STATIC SENSORS: rigid copper,
hard drawn, to ANSI H 23.1 and ASTM B88
standards
INTERNAL FITTINGS: copper, to ANSI
B16.22 standards
PROCESS CONNECTIONS: 1/2-in. NPT
Female

ORDERING INFORMATION

CASING DESIGN

- 3 - Rectangular with no flanges
- 4 - Flat oval with no flanges
- 5 - Round with no flanges
- 6 - Rectangular with angle flanges
- 7 - Flat oval with angle flanges
- 8 - Round with angle flanges
- 9 - Rectangular with sheet metal flanges
- Z - Special

MATERIALS

- 1 - Standard - 16-ga. galv. casing, aluminum straightening vanes, copper probes
- 2 - All stainless steel
- 3 - Stainless steel casing
- 4 - Stainless steel straightening vanes
- 5 - Stainless steel probes
- 6 - Stainless steel casing & straightening vanes
- 7 - Stainless steel casing & probes
- 8 - Stainless steel straightening vanes & probes
- 9 - Coated (specify)
- Z - Special

PROBE/STRAIGHTENING VANE DESIGN

- 1 - Standard-3/8" straightening vanes, multiple total, single bullet-nose static
- 2 - 3/4" straightening vanes (produces approx. 50% of specified pressure drop)
- 3 - Multiple static probes on cylinder surface
- 4 - Multiple bullet-nose static probes
- 5 - 2 & 3 above
- 6 - 2 & 4 above
- Z - Special

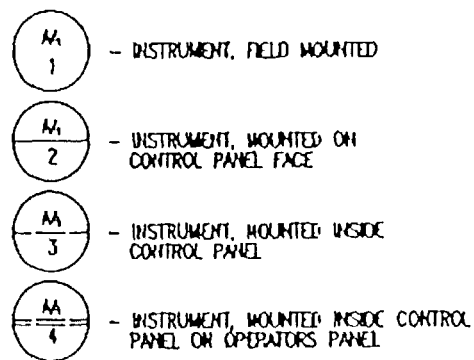
DIMENSIONS: long side x short side or diameter

OPTIONS

- B - Bolt holes in flanges (specify)
- C - Special instrument connections (specify)
- D - Damper with actuator (specify)
- H - Above standard process air pressure (specify)
- W - All welded construction
- Z - Special

ULTRACAMS - () x ()

NOTE: Materials and design are standard unless noted otherwise. For special options, please contact ULTRATECH. Standard stainless steel is type 304. For other alloy, please specify.

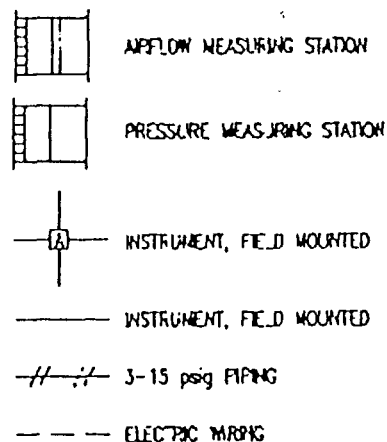


INSTRUMENT DESIGNATORS

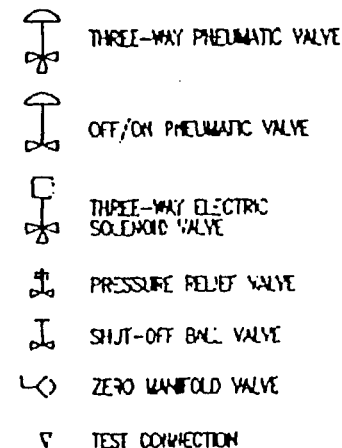
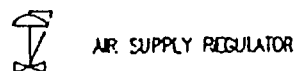
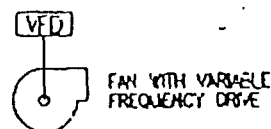
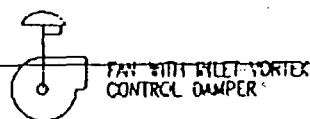
FI - FLOW INDICATOR
 FT - FLOW TRANSMITTER
 FC - FLOW CONTROLLER
 FY - FLOW COMPUTING RELAY
 PI - PRESSURE INDICATOR
 PT - PRESSURE TRANSMITTER
 PC - PRESSURE CONTROLLER
 PS - PRESSURE SWITCH, ELECTRIC
 PY - PRESSURE COMPUTING RELAY
 HC - HAND CONTROL
 SP - SETPOINT
 FN - FILTER
 VOI - VOLUME TANK
 LCD - LIQUID CRYSTAL DISPLAY
 AM - ANALOG METER
 GND - GROUND

RELAY FUNCTION DESIGNATORS

A+B-C - TOTALIZING
 ✓ - SQUARE ROOT EXTRACTOR
 Y : X - FLOW CHARACTERIZING, RATIO
 > - HIGH SELECT
 < - LOW SELECT
 PI - PROPORTIONAL, INTEGRAL RESET PLUS INVERSE DERIVATIVE
 AS1 - PRIMARY AIR SUPPLY 30-150 psig
 AS2 - FILTERED, 20 psig AIR SUPPLY
 ▼ - INSTRUMENT AIR CONNECTION



PANEL CONDUIT CONNECTION - LETTER DENOTES IDENTIFICATION AT CONTROL PANEL



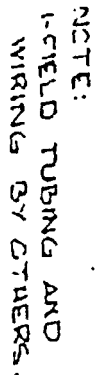
ATO AIR TO OPEN
 ATC AIR TO CLOSE

TERMINAL BLOCK CONNECTION

FILTER

0-15 psig INDICATOR

UT ULTRATECH	
CARMER, NORTH CAROLINA, U.S.A.	
DRAWN BY: WAH	DATE: 2-14-94
APPROVALS:	
TITLE: SYMBOLS FOR DRAWINGS	
UT NO. 042	
REV:	



EPA Method 1

40 CFR 60

2. Procedure

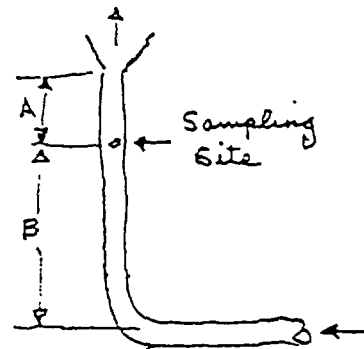
2.1 Selection of Measurement Site. Sampling or velocity measurement is performed at a site located at least eight stack or duct diameters downstream and two diameters upstream from any flow disturbance such as a bend, expansion, or contraction in the stack, or from a visible flame. If necessary, an alternative location may be selected, at a position at least two stack or duct diameters downstream and a half diameter upstream from any flow disturbance. For a rectangular cross section, an equivalent diameter (D_{ie}) shall be calculated from the following equation, to determine the upstream and downstream distances:
To view Figure, TAB to this link, then press ENTER. There will be a pause while the figure-viewing software loads.

An alternative procedure is available for determining the acceptability of a measurement location not meeting the criteria above. This procedure, determination of gas flow angles at the sampling points and comparing the results with acceptability criteria, is described in Section 2.5.

2.2 Determining the Number of Traverse Points.
To view Figure, TAB to this link, then press ENTER. There will be a pause while the figure-viewing software loads.

2.2.1 Particulate Traverses. When the eight- and two-diameter criterion can be met, the minimum number of traverse points shall be: (1) twelve, for circular or rectangular stacks with diameters (or equivalent diameters) greater than 0.61 meter (24 in.); (2) eight, for circular stacks with diameters between 0.30 and 0.61 meter (12-24 in.); (3) nine, for rectangular stacks with equivalent diameters between 0.30 and 0.61 meter (12-24 in.).

When the eight- and two-diameter criterion cannot be met, the minimum number of traverse points is determined from Figure 1-1. Before referring to the figure, however, determine the distances from the chosen measurement site to the nearest upstream and downstream disturbances, and divide each distance by the stack diameter or equivalent diameter, to determine the distance in terms of the number of duct diameters. Then, determine from Figure 1-1 the minimum number of traverse points that corresponds: (1) to the number of duct diameters upstream; and (2) to the number of diameters downstream. Select the higher of the two minimum numbers of traverse points, or a greater value, so that for circular stacks the number is a multiple of 4, and for rectangular stacks, the number is one of those shown in Table 1-1.



Distance (diameters)		No of sampling points per traverse
A	B	
0.5 to 1.25	2 to 5	24
1.25 to 1.50	5 to 6	20
1.50 to 1.75	6 to 7	16

NOTE: EPA METHOD 2 DETAILS CALCULATIONS FOR FLOW RATE DETERMINATION.

Table 1-1. Cross-Section Layout for Rectangular Stacks

Number of traverse points	Matrix layout
9.....	3x3
12.....	4x3
16.....	4x4
20.....	5x4
25.....	5x5
30.....	6x5
36.....	6x6
42.....	7x6
49.....	7x7

To view Figure, TAB to this link, then press ENTER. There will be a pause while the figure-viewing software loads.

2.2.2 Velocity (Non-Particulate) Traverses. When velocity or volumetric flow rate is to be determined (but not particulate matter), the same procedure as that for particulate traverses (Section 2.2.1) is followed, except that Figure 1-2 may be used instead of Figure 1-1.

2.3 Cross-sectional Layout and Location of Traverse Points.

2.3.1 Circular Stacks. Locate the traverse points on two perpendicular diameters according to Table 1-2 and the example shown in Figure 1-3. Any equation (for examples, see Citations 2 and 3 in the Bibliography) that gives the same values as those in Table 1-2 may be used in lieu of Table 1-2.

→ For particulate traverses, one of the diameters must be in a plane containing the greatest expected concentration variation, e.g., after bends, one diameter shall be in the plane of the bend. This requirement becomes less critical as the distance from the disturbance increases; therefore, other diameter locations may be used, subject to approval of the Administrator.

In addition for stacks having diameters greater than 0.61 m (24 in.) no traverse points shall be located within 2.5 centimeters (1.00 in.) of the stack walls; and for stack diameters equal to or less than 0.61 m (24 in.), no traverse points shall be located within 1.3 cm (0.50 in.) of the stack walls. To meet these criteria, observe the procedures given below.

2.3.1.1 Stacks With Diameters Greater Than 0.61 m (24 in.).

When any of the traverse points as located in Section 2.3.1 fall within 2.5 cm (1.00 in.) of the stack walls, relocate them away from the stack walls to: (1) a distance of 2.5 cm (1.00 in.); or (2) a distance equal to the nozzle inside diameter, whichever is larger. These relocated traverse points (on each end of a diameter) shall be the "adjusted" traverse points.

Whenever two successive traverse points are combined to form a single adjusted traverse point, treat the adjusted point as two separate traverse points, both in the sampling (or velocity measurement) procedure, and in recording the data.

To view Figure, TAB to this link, then press ENTER. There will be a pause while the figure-viewing software loads.

Table 1-2. Location of Traverse Points in Circular Stacks

inside
[Percent of stack diameter from inside wall to traverse point]
Number of traverse points on a diameter--

Traverse point number on a di- ameter	2	4	6	8	10	12	14	16	18	20
1.....	14.6	6.7	4.4	3.2	2.6	2.1	1.8	1.6	1.4	1.3
2.....	85.4	25.0	14.6	10.5	8.2	6.7	5.7	4.9	4.4	3.9
3.....		75.0	29.6	19.4	14.6	11.8	9.9	8.5	7.5	6.7
4.....		93.3	70.4	32.3	22.6	17.7	14.6	12.5	10.9	9.7
5.....			85.4	67.7	34.2	25.0	20.1	16.9	14.6	12.9
6.....			95.6	80.6	65.8	35.6	26.9	22.0	18.8	16.5
7.....				89.5	77.4	64.4	36.6	28.3	23.6	20.4
8.....				96.8	85.4	75.0	63.4	37.5	29.6	25.0
9.....					91.8	82.3	73.1	62.5	38.2	30.6
10.....					97.4	88.2	79.9	71.7	61.8	38.8
11.....						93.3	85.4	78.0	70.4	61.2
12.....						97.9	90.1	83.1	76.4	69.4
13.....							94.3	87.5	81.2	75.0
14.....							98.2	91.5	85.4	79.6
15.....								95.1	89.1	83.5
16.....								98.4	92.5	87.1
17.....									95.6	90.3
18.....									98.6	93.3
19.....										96.1
20.....										98.7
21.....										
22.....										
23.....										
24.....										

Traverse

point number
on a di-
ameter

	22	24
1.....	1.1	1.1
2.....	3.5	3.2
3.....	6.0	5.5
4.....	8.7	7.9
5.....	11.6	10.5
6.....	14.6	13.2
7.....	18.0	16.1
8.....	21.8	19.4
9.....	26.2	23.0
10.....	31.5	27.2
11.....	39.3	32.3
12.....	60.7	39.8
13.....	68.5	60.2
14.....	73.8	67.7
15.....	78.2	72.8
16.....	82.0	77.0
17.....	85.4	80.6
18.....	88.4	83.9
19.....	91.3	86.8
20.....	94.0	89.5
21.....	96.5	92.1
22.....	98.9	94.5
23.....	96.8
24.....	98.9

2.3.1.2 Stacks With Diameters Equal to or Less Than 0.61 m (24 in.). Follow the procedure in Section 2.3.1.1, noting only that any "adjusted" points should be relocated away from the stack walls to: (1) a distance of 1.3 cm (0.50 in.); or (2) a distance equal to the nozzle inside diameter, whichever is larger.

2.3.2 Rectangular Stacks. Determine the number of traverse points as explained in Sections 2.1 and 2.2 of this method. From Table 1-1, determine the grid configuration. Divide the stack cross-section into as many equal rectangular elemental areas as traverse points, and then locate a traverse point at the centroid of each equal area according to the example in Figure 1-4.

If the tester desires to use more than the minimum number of traverse points, expand the "minimum number of traverse points" matrix (see Table 1-1) by adding the extra traverse points along one or the other or both legs of the matrix; the final matrix need not be balanced. For example, if a 4x3 "minimum number of points" matrix were expanded to 36 points, the final matrix could

be 9x4 or 12x3, and would not necessarily have to be 6x6. After constructing the final matrix, divide the stack cross-section into as many equal rectangular, elemental areas as traverse points, and locate a traverse point at the centroid of each equal area.

The situation of traverse points being too close to the stack walls is not expected to arise with rectangular stacks. If this problem should ever arise, the Administrator must be contacted for resolution of the matter.

2.4 Verification of Absence of Cyclonic Flow. In most stationary sources, the direction of stack gas flow is essentially parallel to the stack walls. However, cyclonic flow may exist (1) after such devices as cyclones and inertial demisters following venturi scrubbers, or (2) in stacks having tangential inlets or other duct configurations which tend to induce swirling; in these instances, the presence or absence of cyclonic flow at the sampling location must be determined. The following techniques are acceptable for this determination. To view Figure, TAB to this link, then press ENTER. There will be a pause while the figure-viewing software loads.

Level and zero the manometer. Connect a Type S pitot tube to the manometer. Position the Type S pitot tube at each traverse point, in succession, so that the planes of the face openings of the pitot tube are perpendicular to the stack cross-sectional plane; when the Type S pitot tube is in this position, it is at "0° reference." Note the differential pressure (Σp) reading at each traverse point. If a null (zero) pitot reading is obtained at 0° reference at a given traverse point, an acceptable flow condition exists at that point. If the pitot reading is not zero at 0° reference, rotate the pitot tube (up to $\pm 90^\circ$ yaw angle), until a null reading is obtained. Carefully determine and record the value of the rotation angle (α) to the nearest degree. After the null technique has been applied at each traverse point, calculate the average of the absolute values of α ; assign a values of 0° to those points for which no rotation was required, and include these in the overall average. If the average value of α is greater than 20°, the overall flow condition in the stack is unacceptable and alternative methodology, subject to the approval of the Administrator, must be used to perform accurate sample and velocity traverses.

The alternative procedure described in Section 2.5 may be used to determine the rotation angles in lieu of the procedure described above.

APPENDIX G

Flow Measurement Test Report,
Prepared by Atlantic® Environmental Technologies, Inc.,
dated September 19, 1996

FLOW MEASUREMENT TEST REPORT
FS-12 SOIL VAPOR EXTRACTION / SPARGING SYSTEM
OTIS ANG BASE, MA

SUBMITTED TO:

Mr. Dave Gardner
Dave Gardner Contractor, Inc.
300 County Road, P.O. Box 599
Monument Beach, MA 02553

Mr. Joseph H. Hawk, P.E. & Mr. John McDowell, P.E.
Advanced Sciences, Inc.
800 Oak Ridge Turnpike, Suite C-102
Oak Ridge, TN 37830-6927

PREPARED BY:

ATLANTIC ENVIRONMENTAL TECHNOLOGIES, INC.
P.O. Box 1051
Sandwich, MA. 02563

September 19, 1996

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B	Transcribed Data	
C	Field Data	

1.0 INTRODUCTION / SUMMARY

FS-12 is being remediated by a field of air sparging and soil vapor extraction wells that discharge soil vapors to a catalytic oxidation system for treatment. Historical flow measurements to the catalytic oxidation unit are believed to be unreliable due to the location of the pitot tube sensing unit. The rule of thumb that is generally used in locating standard pitot tube measuring devices is a minimum of 8 duct diameters downstream of the nearest upstream flow disturbance, and 2 duct diameters upstream of the nearest downstream flow disturbance. These requirements can be relaxed if measures are taken to dampen the turbulence caused by flow disturbances, e.g., with use of straightening vanes or a honeycomb. The pitot tube device that was originally used in the FS-12 unit had a honeycomb to straighten flow. It was reported that the manufacturer of this device recommended locating the sensing unit 5 duct diameters downstream of the closest flow disturbance. Due to tight clearances within the skid mounted unit, the flow sensor was located immediately downstream of a 45 degree elbow. Based upon conventional practice and reported manufacturer's recommendations, this is not a desirable location.

Atlantic was asked to establish the actual flow rate to the unit by performing flow measurements in accordance with EPA Methods 1 and 2 at an alternate location, i.e., between the particle filter and the air/water separator. This location provides more distance from flow disturbances and will be used for installation of a new flow element manufactured by ULTRATECH. Additionally, a flow correction factor was established to correct historical flow measurement data for inaccuracies introduced by the location of the original primary flow element and other contributing factors.

On Friday, September 13, 1996, air flow measurement tests were conducted in accordance with EPA Methods 1 and 2 at the new location. Since the new ULTRATECH device will use two test ports that are positioned on two different planes, only one of the permanent ULTRATECH test ports was utilized, and a temporary test port was drilled in the pipe to allow two perpendicular traverses to be made in the same plane. A total of three test runs were conducted with the following results:

Run No.	Flow Rate	
	(acfm)	(dscfm)
1	2,922.8	2,665.3
2	3,135.3	2,864.7
3	3,125.6	2,842.1
Average	3,061.2	2,790.7

Immediately following the test, a preliminary result of 3,049 acfm was reported to the Dave Gardner site representative so the ULTRATECH device could be installed and calibrated to be consistent with our flow measurements. The new ULTRATECH device should be recalibrated to account for the revised flow value of 3,061 acfm that was reported on the previous page.

Based on historical flow measurements it was determined that the combination of inaccuracies introduced by both the location of the primary flow element and other contributing factors caused underestimation of system flow and spill remediation efficiency by a factor of 1.28.

2.0 CONDUCT OF TESTING

On Friday, September 13, 1996, flow measurement tests were conducted in accordance with EPA Methods 1 and 2 on the catalytic oxidation treatment unit. The test location was in a straight run of vertical piping between the air/water separator and the inlet particle filter. This location will be used for installation of a new flow element manufactured by ULTRATECH. Since the new ULTRATECH device will use two test ports that are located on two different planes, only one of the permanent ULTRATECH test ports was utilized, and a temporary test port was drilled in the pipe in same plane as that test port. The piping in this location was nominal 12 inch diameter, Schedule 80, PVC. Although a full 8 duct diameters downstream of the nearest upstream flow disturbance, and 2 duct diameters upstream of the nearest downstream flow disturbance was not available, the location exceeded Method 1 minimums. Sixteen (16) test points were selected per traverse in accordance with Method 1, Figure 1-2. Test points were located per Method 1, Table 1-2 using standard dimensions of Schedule 80, 12 inch diameter pipe. Test point locations are shown on Table 1. Pitot tube insertions were controlled to the nearest one tenth of an inch.

Prior to performing the test runs, a cyclonic flow check was made with a Type S pitot tube. The absence of cyclonic flow was confirmed. Three test runs, each consisting of two perpendicular traverses, were made using a standard pitot tube. Temperature measurements were made with a Type K thermocouple. Following the three test runs, a manometer was connected to the previously abandoned primary flow element to determine flow rate measured by that device.

Field data was recorded on standard test forms (Appendix C). Since these forms were damaged by rain, field data was transcribed onto clean forms (Appendix B). Calculations were performed both manually and with a spreadsheet. Calculations, including spreadsheet formulas, are included in Appendix A.

Table 1

TRAVERSE POINT LOCATION - 16 POINTS
12 INCH DIAMETER, SCH 80 PIPE (I.D. = 11.294")

POINT	DISTANCE FROM WALL (% Dia.)	DISTANCE FROM WALL - PIPE FACE (Inches)
16	1.6 (or 0.5 inch, whichever is larger)	0.500 - 1.228 (adjusted)
15	4.9	0.553 - 1.281
14	8.5	0.960 - 1.688
13	12.5	1.412 - 2.140
12	16.9	1.909 - 2.637
11	22.0	2.485 - 3.213
10	28.3	3.196 - 3.924
9	37.5	4.235 - 4.963
8	62.5	7.059 - 7.787
7	71.7	8.098 - 8.826
6	78.0	8.809 - 9.537
5	83.1	9.385 - 10.113
4	87.5	9.882 - 10.610
3	91.5	10.334 - 11.062
2	95.1	10.741 - 11.469
1	98.4 (or I.D. minus 0.5 inch, whichever is smaller)	10.794 - 11.522 (adjusted)

3.0 TEST RESULTS

Flow rate measurements from the three test runs are as follows:

Run No.	Flow Rate	
	(acfm)	(dscfm)
1	2,922.8	2,665.3
2	3,135.3	2,864.7
3	3,125.6	2,842.1
Average	3,061.2	2,790.7

The corresponding flow rate determined from measurement of differential pressure across the original primary flow element was 3,379.1 cfm.

4.0 CONCLUSIONS,

The original flow device provided inaccurate readings. Based on the foregoing test results and conversations with field personnel, contributing factors include the following:

- ◆ location of the primary flow element too close to flow disturbances,
- ◆ the presence of leaks and/or condensation in the sensor lines/fittings leading to the differential pressure transmitter, and
- ◆ potential calibration errors.

Product recovery system tracking data accumulated between October 23, 1995 and July 23, 1996 indicates that the weighted average flow rate to the system (as measured by the original flow meter) was 2,383 cfm for each day of operation (refer to Table 2). Assuming that system flow is not materially affected by seasonal variations or other influences, the test data concludes that the actual average soil vapor flow rate to the system is (was) 3,061 acfm, whereas the value measured by the original flow element (weighted average for each day of operation) was 2,383 cfm. This suggests that a correction factor of 1.28 ($3,061 / 2,383$) can be applied to product system recovery data to account for historical flow measurement inaccuracies.

Table 2
Historical Flow Data - Summary

Period	Operational Days	Average Flow Rate (cfm)
October 23 - 31, 1995	9	3,414
November 1 - 30, 1995	30	2,656
December 1 - 31, 1995	28	2,468
January 1 - 31, 1996	19	1,733
February 1 - 29, 1996	18	2,263
March 1 - 31, 1996	31	2,387
April 1 - 30, 1996	0	0
May 1 - 31, 1996	10	2,175
June 1 - 30, 1996	23	2,232
July 1 - 23, 1996	6	2,386
	174 (Total)	2,383 (Weighted)

APPENDIX A
CALCULATIONS

Method 2 - Calculations									
MMR, FS-12									
Run 1									
Point	Delta P	Sq Rt Delta P	Run 2			Run 3			Sq Rt Del
			Point	Delta P	Sq Rt Delta P	Point	Delta P		
1A,1	1.5	1.224745	1A,1	1.4	1.183216	1A,1	1.7	1.30384	
1A,2	1.6	1.264911	1A,2	1.9	1.378405	1A,2	2	1.414214	
1A,3	1.9	1.378405	1A,3	2	1.414214	1A,3	1.8	1.378405	
1A,4	1.9	1.378405	1A,4	2	1.414214	1A,4	2	1.414214	
1A,5	1.8	1.341641	1A,5	2	1.414214	1A,5	2	1.414214	
1A,6	1.7	1.30384	1A,6	1.9	1.378405	1A,6	1.9	1.378405	
1A,7	1.6	1.264911	1A,7	1.7	1.30384	1A,7	1.6	1.264911	
1A,8	1.2	1.095445	1A,8	1.3	1.140175	1A,8	1.3	1.140175	
1A,9	0.74	0.860233	1A,9	0.76	0.717178	1A,9	0.8	0.894427	
1A,10	0.68	0.824621	1A,10	0.71	0.842615	1A,10	0.72	0.848528	
1A,11	0.65	0.806226	1A,11	0.7	0.83666	1A,11	0.68	0.824621	
1A,12	0.57	0.754983	1A,12	0.71	0.842615	1A,12	0.67	0.818535	
1A,13	0.57	0.754983	1A,13	0.71	0.842615	1A,13	0.62	0.787401	
1A,14	0.56	0.748331	1A,14	0.43	0.655744	1A,14	0.61	0.781025	
1A,15	0.41	0.640312	1A,15	0.66	0.812404	1A,15	0.35	0.591608	
1A,16	0.41	0.640312	1A,16	0.66	0.812404	1A,16	0.35	0.591608	
1B,1	1.7	1.30384	1B,1	1.4	1.183216	1B,1	1.4	1.183216	
1B,2	1.4	1.183216	1B,2	1.5	1.224745	1B,2	1.5	1.224745	
1B,3	1.4	1.183216	1B,3	1.7	1.30384	1B,3	1.7	1.30384	
1B,4	1.6	1.264911	1B,4	1.7	1.30384	1B,4	1.6	1.264911	
1B,5	1.2	1.095445	1B,5	1.7	1.30384	1B,5	1.6	1.264911	
1B,6	1.2	1.095445	1B,6	1.5	1.224745	1B,6	1.5	1.224745	
1B,7	1.1	1.048809	1B,7	1.6	1.264911	1B,7	1.3	1.140175	
1B,8	0.93	0.964365	1B,8	1.3	1.140175	1B,8	1.1	1.048809	
1B,9	0.72	0.848528	1B,9	0.91	0.953939	1B,9	0.96	0.979796	
1B,10	0.75	0.866025	1B,10	0.63	0.793725	1B,10	1.1	1.048809	
1B,11	0.79	0.88819	1B,11	1.1	1.048809	1B,11	1.2	1.095445	
1B,12	0.82	0.905539	1B,12	1.1	1.048809	1B,12	1.3	1.140175	
1B,13	0.82	0.905539	1B,13	1.1	1.048809	1B,13	1	1	
1B,14	0.86	0.927362	1B,14	1	1	1B,14	1	1	
1B,15	0.8	0.894427	1B,15	0.96	0.979796	1B,15	1	1	
1B,16	0.8	0.894427	1B,16	0.96	0.979796	1B,16	1	1	
Average		1.017	Average		1.092	Average		1.086	
T (deg F)		59			58			60.5	
T (deg R)		519			518			520.5	
Pbar		29.85			29.85			29.85	
Vs (fps)		70.02045			75.11173			74.87907	
Q (acfm)		2922.798			3135.318			3125.606	
Qsd (dscfm)		2665.339			2864.659			2842.069	

A	A	B	C	D	E	F	G	H	I	J	K
1	Method 2 - Calculations										
2	MMR, FS-12										
3											
4	Run 1			Run 2			Run 3				
5	Point	Delta P	Sq Rt Delta P	Point	Delta P	Sq Rt Delta P	Point	Delta P	Sq Rt Del		
6	1A,1	1.5	1.224745	1A,1	1.4	1.183216	1A,1	1.7	1.30384		
7	1A,2	1.6	1.264911	1A,2	1.9	1.378405	1A,2	2	1.414214		
8	1A,3	1.9	1.378405	1A,3	2	1.414214	1A,3	1.9	1.378405		
9	1A,4	1.9	1.378405	1A,4	2	1.414214	1A,4	2	1.414214		
10	1A,5	1.8	1.341641	1A,5	2	1.414214	1A,5	2	1.414214		
11	1A,6	1.7	1.30384	1A,6	1.9	1.378405	1A,6	1.9	1.378405		
12	1A,7	1.6	1.264911	1A,7	1.7	1.30384	1A,7	1.6	1.264911		
13	1A,8	1.2	1.095445	1A,8	1.3	1.140175	1A,8	1.3	1.140175		
14	1A,9	0.74	0.860233	1A,9	0.76	0.87178	1A,9	0.8	0.894427		
15	1A,10	0.68	0.824621	1A,10	0.71	0.842615	1A,10	0.72	0.848528		
16	1A,11	0.65	0.806226	1A,11	0.7	0.83666	1A,11	0.68	0.824621		
17	1A,12	0.57	0.754983	1A,12	0.71	0.842615	1A,12	0.67	0.818535		
18	1A,13	0.57	0.754983	1A,13	0.71	0.842615	1A,13	0.62	0.787401		
19	1A,14	0.56	0.748331	1A,14	0.43	0.655744	1A,14	0.61	0.781025		
20	1A,15	0.41	0.640312	1A,15	0.66	0.812404	1A,15	0.35	0.591608		
21	1A,16	0.41	0.640312	1A,16	0.66	0.812404	1A,16	0.35	0.591608		
22	1B,1	1.7	1.30384	1B,1	1.4	1.183216	1B,1	1.4	1.183216		
23	1B,2	1.4	1.183216	1B,2	1.5	1.224745	1B,2	1.5	1.224745		
24	1B,3	1.4	1.183216	1B,3	1.7	1.30384	1B,3	1.7	1.30384		
25	1B,4	1.6	1.264911	1B,4	1.7	1.30384	1B,4	1.6	1.264911		
26	1B,5	1.2	1.095445	1B,5	1.7	1.30384	1B,5	1.6	1.264911		
27	1B,6	1.2	1.095445	1B,6	1.5	1.224745	1B,6	1.5	1.224745		
28	1B,7	1.1	1.048809	1B,7	1.6	1.264911	1B,7	1.3	1.140175		
29	1B,8	0.93	0.964365	1B,8	1.3	1.140175	1B,8	1.1	1.048809		
30	1B,9	0.72	0.848528	1B,9	0.91	0.953939	1B,9	0.96	0.979796		
31	1B,10	0.75	0.866025	1B,10	0.63	0.793725	1B,10	1.1	1.048809		
32	1B,11	0.79	0.888819	1B,11	1.1	1.048809	1B,11	1.2	1.095445		
33	1B,12	0.82	0.905539	1B,12	1.1	1.048809	1B,12	1.3	1.140175		
34	1B,13	0.82	0.905539	1B,13	1.1	1.048809	1B,13	1	1		
35	1B,14	0.86	0.927362	1B,14	1	1	1B,14	1	1		
36	1B,15	0.8	0.894427	1B,15	0.96	0.979796	1B,15	1	1		
37	1B,16	0.8	0.894427	1B,16	0.96	0.979796	1B,16	1	1		
38	Average		1.017	Average		1.092	Average		1.086		
39											
40	T (deg F)		59			58			60.5		
41	T (deg R)		519			518			520.5		
42	Pbar		29.85			29.85			29.85		
43	Vs (fps)		70.02045			75.11173			74.87907		
44	Q (acfm)		2922.798			3135.318			3125.606		
45	Qsd (dscfm)		2665.339			2864.659			2842.069		

A:A1: 'Method 2 - Calculations
A:A2: 'MMR, FS-12
A:A4: 'Run 1
A:E4: 'Run 2
A:I4: 'Run 3
A:A5: 'Point
A:B5: 'Delta P
A:C5: 'Sq Rt Delta P
A:E5: 'Point
A:F5: 'Delta P
A:G5: 'Sq Rt Delta P
A:I5: 'Point
A:J5: 'Delta P
A:K5: 'Sq Rt Delta P
A:A6: ^1A,1
A:B6: 1.5
A:C6: +B6^0.5
A:E6: ^1A,1
A:F6: 1.4
A:G6: +F6^0.5
A:I6: ^1A,1
A:J6: 1.7
A:K6: +J6^0.5
A:A7: ^1A,2
A:B7: 1.6
A:C7: +B7^0.5
A:E7: ^1A,2
A:F7: 1.9
A:G7: +F7^0.5
A:I7: ^1A,2
A:J7: 2
A:K7: +J7^0.5
A:A8: ^1A,3
A:B8: 1.9
A:C8: +B8^0.5
A:E8: ^1A,3
A:F8: 2
A:G8: +F8^0.5
A:I8: ^1A,3
A:J8: 1.9
A:K8: +J8^0.5
A:A9: ^1A,4
A:B9: 1.9
A:C9: +B9^0.5
A:E9: ^1A,4
A:F9: 2
A:G9: +F9^0.5
A:I9: ^1A,4
A:J9: 2
A:K9: +J9^0.5
A:A10: ^1A,5
A:B10: 1.8
A:C10: +B10^0.5
A:E10: ^1A,5
A:F10: 2
A:G10: +F10^0.5
A:I10: ^1A,5
A:J10: 2
A:K10: +J10^0.5

A:A11: ^1A,6
A:B11: 1.7
A:C11: +B11^0.5
A:E11: ^1A,6
A:F11: 1.9
A:G11: +F11^0.5
A:I11: ^1A,6
A:J11: 1.9
A:K11: +J11^0.5
A:A12: ^1A,7
A:B12: 1.6
A:C12: +B12^0.5
A:E12: ^1A,7
A:F12: 1.7
A:G12: +F12^0.5
A:I12: ^1A,7
A:J12: 1.6
A:K12: +J12^0.5
A:A13: ^1A,8
A:B13: 1.2
A:C13: +B13^0.5
A:E13: ^1A,8
A:F13: 1.3
A:G13: +F13^0.5
A:I13: ^1A,8
A:J13: 1.3
A:K13: +J13^0.5
A:A14: ^1A,9
A:B14: 0.74
A:C14: +B14^0.5
A:E14: ^1A,9
A:F14: 0.76
A:G14: +F14^0.5
A:I14: ^1A,9
A:J14: 0.8
A:K14: +J14^0.5
A:A15: ^1A,10
A:B15: 0.68
A:C15: +B15^0.5
A:E15: ^1A,10
A:F15: 0.71
A:G15: +F15^0.5
A:I15: ^1A,10
A:J15: 0.72
A:K15: +J15^0.5
A:A16: ^1A,11
A:B16: 0.65
A:C16: +B16^0.5
A:E16: ^1A,11
A:F16: 0.7
A:G16: +F16^0.5
A:I16: ^1A,11
A:J16: 0.68
A:K16: +J16^0.5
A:A17: ^1A,12
A:B17: 0.57
A:C17: +B17^0.5
A:E17: ^1A,12
A:F17: 0.71

A:G17:	+F17^0.5
A:I17:	^1A,12
A:J17:	0.67
A:K17:	+J17^0.5
A:A18:	^1A,13
A:B18:	0.57
A:C18:	+B18^0.5
A:E18:	^1A,13
A:F18:	0.71
A:G18:	+F18^0.5
A:I18:	^1A,13
A:J18:	0.62
A:K18:	+J18^0.5
A:A19:	^1A,14
A:B19:	0.56
A:C19:	+B19^0.5
A:E19:	^1A,14
A:F19:	0.43
A:G19:	+F19^0.5
A:I19:	^1A,14
A:J19:	0.61
A:K19:	+J19^0.5
A:A20:	^1A,15
A:B20:	0.41
A:C20:	+B20^0.5
A:E20:	^1A,15
A:F20:	0.66
A:G20:	+F20^0.5
A:I20:	^1A,15
A:J20:	0.35
A:K20:	+J20^0.5
A:A21:	^1A,16
A:B21:	0.41
A:C21:	+B21^0.5
A:E21:	^1A,16
A:F21:	0.66
A:G21:	+F21^0.5
A:I21:	^1A,16
A:J21:	0.35
A:K21:	+J21^0.5
A:A22:	^1B,1
A:B22:	1.7
A:C22:	+B22^0.5
A:E22:	^1B,1
A:F22:	1.4
A:G22:	+F22^0.5
A:I22:	^1B,1
A:J22:	1.4
A:K22:	+J22^0.5
A:A23:	^1B,2
A:B23:	1.4
A:C23:	+B23^0.5
A:E23:	^1B,2
A:F23:	1.5
A:G23:	+F23^0.5
A:I23:	^1B,2
A:J23:	1.5
A:K23:	+J23^0.5
A:A24:	^1B,3

A:B24: 1.4
A:C24: $+B24^{0.5}$
A:E24: 1B,3
A:F24: 1.7
A:G24: $+F24^{0.5}$
A:I24: 1B,3
A:J24: 1.7
A:K24: $+J24^{0.5}$
A:A25: 1B,4
A:B25: 1.6
A:C25: $+B25^{0.5}$
A:E25: 1B,4
A:F25: 1.7
A:G25: $+F25^{0.5}$
A:I25: 1B,4
A:J25: 1.6
A:K25: $+J25^{0.5}$
A:A26: 1B,5
A:B26: 1.2
A:C26: $+B26^{0.5}$
A:E26: 1B,5
A:F26: 1.7
A:G26: $+F26^{0.5}$
A:I26: 1B,5
A:J26: 1.6
A:K26: $+J26^{0.5}$
A:A27: 1B,6
A:B27: 1.2
A:C27: $+B27^{0.5}$
A:E27: 1B,6
A:F27: 1.5
A:G27: $+F27^{0.5}$
A:I27: 1B,6
A:J27: 1.5
A:K27: $+J27^{0.5}$
A:A28: 1B,7
A:B28: 1.1
A:C28: $+B28^{0.5}$
A:E28: 1B,7
A:F28: 1.6
A:G28: $+F28^{0.5}$
A:I28: 1B,7
A:J28: 1.3
A:K28: $+J28^{0.5}$
A:A29: 1B,8
A:B29: 0.93
A:C29: $+B29^{0.5}$
A:E29: 1B,8
A:F29: 1.3
A:G29: $+F29^{0.5}$
A:I29: 1B,8
A:J29: 1.1
A:K29: $+J29^{0.5}$
A:A30: 1B,9
A:B30: 0.72
A:C30: $+B30^{0.5}$
A:E30: 1B,9
A:F30: 0.91
A:G30: $+F30^{0.5}$

A:I30:	1B,9
A:J30:	0.96
A:K30:	$+J30^{0.5}$
A:A31:	1B,10
A:B31:	0.75
A:C31:	$+B31^{0.5}$
A:E31:	1B,10
A:F31:	0.63
A:G31:	$+F31^{0.5}$
A:I31:	1B,10
A:J31:	1.1
A:K31:	$+J31^{0.5}$
A:A32:	1B,11
A:B32:	0.79
A:C32:	$+B32^{0.5}$
A:E32:	1B,11
A:F32:	1.1
A:G32:	$+F32^{0.5}$
A:I32:	1B,11
A:J32:	1.2
A:K32:	$+J32^{0.5}$
A:A33:	1B,12
A:B33:	0.82
A:C33:	$+B33^{0.5}$
A:E33:	1B,12
A:F33:	1.1
A:G33:	$+F33^{0.5}$
A:I33:	1B,12
A:J33:	1.3
A:K33:	$+J33^{0.5}$
A:A34:	1B,13
A:B34:	0.82
A:C34:	$+B34^{0.5}$
A:E34:	1B,13
A:F34:	1.1
A:G34:	$+F34^{0.5}$
A:I34:	1B,13
A:J34:	1
A:K34:	$+J34^{0.5}$
A:A35:	1B,14
A:B35:	0.86
A:C35:	$+B35^{0.5}$
A:E35:	1B,14
A:F35:	1
A:G35:	$+F35^{0.5}$
A:I35:	1B,14
A:J35:	1
A:K35:	$+J35^{0.5}$
A:A36:	1B,15
A:B36:	0.8
A:C36:	$+B36^{0.5}$
A:E36:	1B,15
A:F36:	0.96
A:G36:	$+F36^{0.5}$
A:I36:	1B,15
A:J36:	1
A:K36:	$+J36^{0.5}$
A:A37:	1B,16
A:B37:	0.8

A:C37: $+B37^{0.5}$
 A:E37: 1B,16
 A:F37: 0.96
 A:G37: $+F37^{0.5}$
 A:I37: 1B,16
 A:J37: 1
 A:K37: $+J37^{0.5}$
 A:A38: ^Average
 A:C38: @ROUND(@AVG(C6..C37),3)
 A:E38: ^Average
 A:G38: @ROUND(@AVG(G6..G37),3)
 A:I38: ^Average
 A:K38: @ROUND(@AVG(K6..K37),3)
 A:A40: T (deg F)
 A:C40: 59
 A:G40: 58
 A:K40: 60.5
 A:A41: T (deg R)
 A:C41: $+C40+460$
 A:G41: $+G40+460$
 A:K41: $+K40+460$
 A:A42: 'Pbar
 A:C42: 29.85
 A:G42: 29.85
 A:K42: 29.85
 A:A43: 'Vs (fps)
 A:C43: $85.49^{0.99} \cdot C38^{((C41)/((C42-36/13.6)^{28.83}))^{0.5}}$
 A:G43: $85.49^{0.99} \cdot G38^{((G41)/((G42-36/13.6)^{28.83}))^{0.5}}$
 A:K43: $85.49^{0.99} \cdot K38^{((K41)/((K42-36/13.6)^{28.83}))^{0.5}}$
 A:A44: 'Q (acfm)
 A:C44: @ROUND(C43*60*(3.14159/4)*(11.294/12)^2,3)
 A:G44: @ROUND(G43*60*(3.14159/4)*(11.294/12)^2,3)
 A:K44: @ROUND(K43*60*(3.14159/4)*(11.294/12)^2,3)
 A:A45: 'Qsd (dscfm)
 A:C45: $+C44^{(1-0.0141)} \cdot (528/C41)^{((C42-36/13.6)/29.92)}$
 A:G45: $+G44^{(1-0.0141)} \cdot (528/G41)^{((G42-36/13.6)/29.92)}$
 A:K45: $+K44^{(1-0.0141)} \cdot (528/K41)^{((K42-36/13.6)/29.92)}$

Stack Gas Molecule Weight

Dry Bulb Temp. = 61°F

Wet Bulb Temp. = 54°F

Barometric Pressure = 29.85 in Hg

Static Pressure = $-36 \text{ in H}_2\text{O}$

$P_w = 0.4203 \text{ in Hg}$

$$W = 0.62198 \left(\frac{P_w}{P - P_w} \right) = 0.62198 \left(\frac{P_w}{[(P_B - P_s) - P_w]} \right)$$

$$= \frac{0.62198 (0.4203)}{29.85 - 36/13.6 - 0.4203} = 0.00976 \frac{\text{lb moist}}{\text{lb dry air}}$$

$PV = nRT$

$$n = (n_{\text{moist}} + n_{\text{dry air}}) = \frac{m_{\text{moist}}}{MW_{\text{H}_2\text{O}}} + \frac{m_{\text{air}}}{MW_{\text{air}}} = \frac{m_{\text{tot}}}{MW_s}$$

$$\frac{0.00976}{18} + \frac{1}{29} = \frac{1.00976}{MW_s}$$

$$0.0350 = \frac{1.00976}{MW_s}$$

$$MW_s = 28.83$$

Stack Gas Moisture

$B_{ws} =$ Proportion of water vapor in gas stream by volume
(Equals mol proportion)

$$= \frac{n_{\text{moist}}}{n_{\text{moist}} + n_{\text{dry air}}}$$

$$= \frac{0.00976/18}{0.00976/18 + 1/29}$$

$$= 0.0155$$

Flow Measured by Original Primary Flow Element

Differential Pressure - 1.3 in H₂O

$$\text{Flow Rate (CFM)} = \sqrt{\text{IN. WC}} \times 4005 \times \text{Effective Area}$$

where the effective area is 0.74 ft²

$$\text{Flow Rate} = \sqrt{1.3} \times 4005 \times 0.74 = 3379.1 \text{ CFM}$$

CALCULATIONS

Velocity Pressure (IN. W.C.) = Total Pressure - Static Pressure

Velocity Pressure (IN. W.C.) = $(\text{CFM}/\text{Effective Area}/4005)^2$

Volume (CFM) = $\sqrt{\text{IN. W.C.}} \times 4005 \times \text{Effective Area}$

Velocity (CFM) = FPM \times Effective Area

Velocity (FPM) = CFM/Effective Area

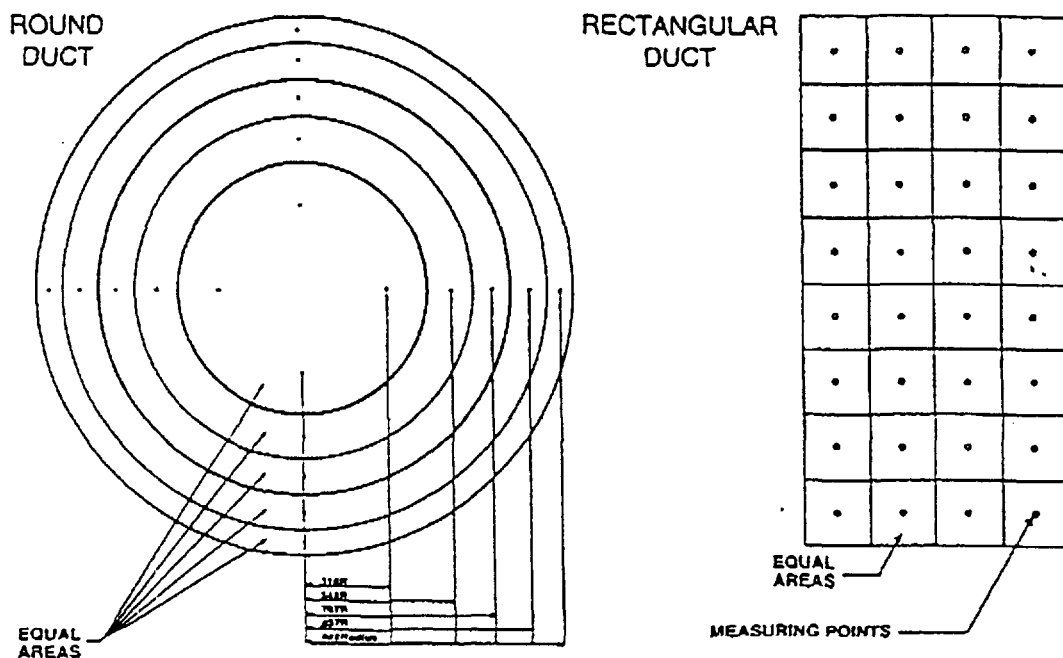
Velocity (FPM) = $4005 \times \sqrt{\text{IN. W.C.}}$

AIRFLOW MEASURING CONSIDERATIONS

The Pitot tube is the primary standard used to calibrate all other airflow measuring devices. Therefore, it is a natural application for use in devices that measure airflow in ducts and pipes for HVAC or industrial processes. Since a single Pitot tube is greatly affected by variations of the flow profile across the duct, multiple Pitots connected in an averaging arrangement will provide much greater accuracy and repeatability for control purposes. Even multiple averaging Pitots are affected by turbulence so straightening vanes are incorporated into ULTRAC Airflow Measuring Stations to prevent turbulence-produced errors.

The figures below illustrate the fixed traverse pattern used to determine the layout of measuring points in ULTRAC AMS thus providing the fixed traverse which is standard in the industry.

AREA & MEASUREMENT POINT RELATIONSHIPS



APPENDIX B
TRANSCRIBED DATA

ATLANTIC ENVIRONMENTAL TECHNOLOGIES

P.O. Box 1051 Sandwich, MA 02563
Tel: (508) 888-9282 Fax: (508) 888-5859

EPA TEST METHOD 2

Velocity Traverse and Volumetric Flowrate Determination

Client MMR Proj. No. 5244.13
Facility FS-12
City, State _____
Test Date SEPT. 13, 1996
Test Location Cat Ox Inlet (before Filter)
Test Run No. 1
Stack Dimensions I.D. 11.294 inches Area (As) = 0.6957 ft²

Static Pressure (Pg) = -36 inches H₂O
Barometric Pressure (Pbar) = 29.85 inches Hg
Stack Gas Molecular Weight (MW) = 28.81
Stack Gas Moisture Content (Bws x 100) 1.41
Pitot No. 160-36 Cp = 0.99
Testers HH, WWR

Schematic of Stack / Sampling Points

TEST PORT INFORMATION / DATA

PRIMARY FLOW ELEMENT DATA

PORT	STATIC PRESS.	DEPTH inches	Delta P inches H ₂ O	T stack °F	Delta P inches H ₂ O	Comments
1A	-36	11.5	1.5	59	1.3	
		11.5	1.6			
		11.1	1.9			
		10.6	1.9			
		10.1	1.8			
		9.5	1.7			
		8.8	1.6			
		7.8	1.2			
		5.0	0.74			
		3.9	0.68			
		3.2	0.65			
		2.6	0.57			
		2.1	0.57			
		1.7	0.56			
		1.3	0.41			
		1.2	0.41			

Standard absolute Temperature: Tsd = 528°R Standard absolute Pressure: Psd = 29.92 in Hg

Absolute Gas Temperature: Ts = 460 + Tsk = 519 °R

Absolute Stack Gas Pressure: Ps = Pbar + (Pg / 13.6) = 27.20 in Hg

Stack Gas Velocity: Vs = 85.49 x Cp x [(Delta P)^{0.5}] x [Ts / (Ps x MW)]^{0.5} = _____ ft/sec

Actual Gas Flowrate: Qs = 60 x Vs x As = _____ ACFM

Average Stack Gas Dry Volumetric Flowrate: Qsd = Qs x (1 - Bws) x (Tsd / Ts) x (Ps / Psd) = _____ DSCFM

SEE
SPREAD SHEET

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Velocity Traverse and Volumetric Flowrate Determination

Static Pressure (Pg) = -36 inches H₂O
Barometric Pressure (Pbar) = 29.85 inches Hg
Stack Gas Molecular Weight (MW) = 28.81
Stack Gas Moisture Content (Bws x 100) = 1.41
Pitot No. 160-36 Cp = 0.99
Testers HH, WWS

Schematic of Stack / Sampling Points

TEST PORT INFORMATION / DATA					PRIMARY FLOW ELEMENT DATA		
PORT	STATIC PRESS.	DEPTH inches	Delta P inches H ₂ O	T stat. °F		Delta P inches H ₂ O	Comments
1B	-36	11.5	1.7	59		1.3	
		11.5	1.4				
		11.1	1.4				
		10.6	1.6				
		10.1	1.2				
		9.5	1.2				
		8.8	1.1				
		7.8	0.93				
		5.0	0.72				
		3.9	0.75				
		3.2	0.79				
		2.6	0.82				
		2.1	0.82				
		1.7	0.86				
		1.3	0.80				
		1.2	0.80				

Average Stack Gas Dry Volumetric Flowrate: $Q_{sd} = Q_s \times (1 - B_{ws}) \times (T_{sd} / T_s) \times (P_s / P_{sd}) = \underline{\hspace{2cm}} \text{ DSCFM}$

SEE
SPREAD SHEET

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EPA TEST METHOD 2

Velocity Traverse and Volumetric Flowrate Determination

Client MMR Proj. No. 5244.13
 Facility FS-12
 City, State _____
 Test Date SEPT. 13, 1996
 Test Location Cat O₂ Inlet (before Filter)
 Test Run No. 2
 Stack Dimensions LD. 11.294 inches Area (A_s) = 0.6957 ft²

Static Pressure (P_g) = -36 inches H₂O
 Barometric Pressure (P_{bar}) = 29.85 inches Hg
 Stack Gas Molecular Weight (MW) = 28.81
 Stack Gas Moisture Content (Bws x 100) 1.41
 Pitot No. 160-36 C_p = 0.99
 Testers HH, WKK

Schematic of Stack / Sampling Points

TEST PORT INFORMATION / DATA

PRIMARY FLOW ELEMENT DATA

PORT	STATIC PRESS.	DEPTH inches	Delta P inches H ₂ O	T stack °F	Delta P inches H ₂ O	Comments
1A	-36	11.5	1.4	58	1.3	
		11.5	1.9			
		11.1	2.0			
		10.6	2.0			
		10.1	2.0			
		9.5	1.9			
		8.8	1.7			
		7.8	1.3			
		5.0	0.76			
		3.9	0.71			
		3.2	0.76			
		2.6	0.71			
		2.1	0.71			
		1.7	0.43			
		1.3	0.66			
		1.2	0.66			

Standard absolute Temperature: T_{std} = 528°R Standard absolute Pressure: P_{std} 29.92 in HgAbsolute Gas Temperature: T_s = 460 + T_{sk} = 518 °RAbsolute Stack Gas Pressure: P_s = P_{bar} + (P_g / 13.6) = 27.20 in HgStack Gas Velocity: V_s = 85.49 x C_p x [(Delta P) ^{0.5} / (T_s / (P_s x MW)) ^{0.5}] = _____ ft/secActual Gas Flowrate: Q_a = 60 x V_s x A_s = _____ ACFMAverage Stack Gas Dry Volumetric Flowrate: Q_{sd} = Q_a x (1 - Bws) x (T_{std} / T_s) x (P_s / P_{std}) = _____ DSCFMSEE
SPREAD SHEET

Velocity Traverse and Volumetric Flowrate Determination

Stack Dimensions I.D. _____ inches. Area (A_s) = _____ ft^2

Testers

~ 78% RH
(a) 60° db
57° wb

PRIMARY FLOW ELEMENT DATA

PORT	STATIC PRESS.	DEPTH inches	Delta P inches H ₂ O	T sack °F		Delta P inches H ₂ O	Comments
1B		Pilot	1.7	59		1.3	
			1.4				
			1.4				
			1.6				
			1.7				
			1.2				
			1.1				
			0.93				
			0.77				
			0.75				
			0.79				
			0.82				
			0.81				
			0.86				
			0.87				
			0.83				
AVERAGE		Delta P					

Average Stack Gas Dry Volumetric Flowrate: $Q_{sd} = Q_g \times (1 - B_{ws}) \times (T_{ad} / T_s) \times (P_s / P_{ad}) = \underline{\hspace{2cm}} \text{ DSCFM}$

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Velocity Traverse and Volumetric Flowrate Determination

Schematic of Slack / Sampling Points

Average Stack Gas Dry Volumetric Flowrate: $Q_{sd} = Q_a \times (1 - B_{ws}) \times (T_{sd} / T_s) \times (P_s / P_{sd}) = \underline{\hspace{2cm}} \text{ DSCFM}$

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Velocity Traverse and Volumetric Flowrate Determination

Static Pressure (Pg) = -36" inches H₂O
 Barometric Pressure (Pbar) = _____ inches Hg
 Stack Gas Molecular Weight (MW) = _____
 Stack Gas Moisture Content (Bws x 100) _____
 Pitot No. _____ Cp = _____
 Testers _____

3049 AEFM

PRIMARY FLOW ELEMENT DATA

PORT	STATIC PRESS.	DEPTH inches	Delta P inches H ₂ O	T rack °F		Delta P inches H ₂ O	Comments
.		0.1	1.5	59			
			1.6	1			
			1.9				
			1.7				
			1.8	1			
			1.7	1			
			1.6	1			
			1.2	1		-	
			0.74	1			
			0.69	1			
			0.65	1			
			0.57	1			
			0.57	1			
			0.56	V			
			0.41	V			
AVERAGE	Delta P						

Average Stack Gas Dry Volumetric Flowrate: $Q_{sd} = Q_g \times (1 - B_{ws}) \times (T_{std}/T_s) \times (P_s/P_{std}) =$ _____ DSCFM

APPENDIX C

FIELD DATA

Table 3

METHOD 1, CHECK FOR ABSENCE OF CYCLONIC FLOW

Client: MMR
 Facility: FS-12
 Test Date: Sept. 13, 1996
 Tester: HH

Traverse Point Number	Cyclonic Flow Determination			
	Port	Null Angle (α)	Port	Null Angle (α)
1	1A	7	1B	3
2		8		10
3		6		13
4		13		3
5		4		5
6		3		15
7		3		15
8		3		10
9		9		10
10		10		8
11		9		3
12		7		5
13		7		1
14		4		0
15		1		4
16		1		4
Average		5.9		6.8

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EPA TEST METHOD 2

Velocity Traverse and Volumetric Flowrate Determination

Client MMR Proj. No. 5244.13
 Facility FS-12
 City, State _____
 Test Date SEPT. 13, 1996
 Test Location Cat Ox Inlet (before Filter)
 Test Run No. 3
 Stack Dimensions I.D. 11.294 inches Area (As) = 0.6957 ft²

Static Pressure (Pg) = -36 inches H₂O
 Barometric Pressure (Pbar) = 29.85 inches Hg
 Stack Gas Molecular Weight (MW) = 28.81
 Stack Gas Moisture Content (Bws x 100) 1.41
 Pitot No. 160-36 Cp = 0.99
 Testers HH, WJK

Schematic of Stack / Sampling Points

TEST PORT INFORMATION / DATA

PRIMARY FLOW ELEMENT DATA

PORT	STATIC PRESS.	DEPTH inches	Delta P inches H ₂ O	T stack °F	Delta P inches H ₂ O	Comments
1B	-36	11.5	1.4	60.5	1.3	
		11.5	1.5			
		11.1	1.7			
		10.6	1.6			
		10.1	1.6			
		9.5	1.5			
		8.8	1.3			
		7.8	1.1			
		5.0	0.96			
		3.9	1.1			
		3.2	1.2			
		2.6	1.3			
		2.1	1.0			
		1.7	1.0			
		1.3	1.0			
		1.2	1.0			

Standard absolute Temperature: Tstd = 528°R Standard absolute Pressure: Pstd = 29.92 in HgAbsolute Gas Temperature: Ts = 460 + Tsk = 520.5 °RAbsolute Stack Gas Pressure: Ps = Pbar + (Pg / 13.6) = 27.20 in HgStack Gas Velocity: Vs = 85.49 x Cp x [(Delta P) ^{0.5}] / [Ts / (Ps x MW)] ^{0.5} = _____ ft/sec

Actual Gas Flowrate: Qa = 60 x Vs x As = _____ ACFM

Average Stack Gas Dry Volumetric Flowrate: Qsd = Qa x (1 - Bws) x (Tstd / Ts) x (Ps / Pstd) = _____ DSCFM

SEE
SPREAD SHEET

ATLANTIC ENVIRONMENTAL TECHNOLOGIES

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EPA TEST METHOD 2

Velocity Traverse and Volumetric Flowrate Determination

Client MMR Proj. No. 5244.13
 Facility FS-12
 City, State _____
 Test Date SEPT. 13, 1996
 Test Location Cat Ox Inlet (before Filter)
 Test Run No. 3
 Stack Dimensions I.D. 11.294 inches Area (As) = 0.6957 ft²

Static Pressure (Pg) = -36 inches H₂O
 Barometric Pressure (Pbar) = 29.85 inches Hg
 Stack Gas Molecular Weight (MW) = 28.81
 Stack Gas Moisture Content (Bws x 100) 1.41
 Pitot No. 160-36 Cp = 0.99
 Testers HH, WJK

Schematic of Stack / Sampling Points

TEST PORT INFORMATION / DATA

PRIMARY FLOW ELEMENT DATA

PORT	STATIC PRESS.	DEPTH inches	Delta P inches H ₂ O	T stack °F	Delta P inches H ₂ O	Comments
1A	-36	11.5	1.7	60.5	1.3	
		11.5	2.0			
		11.1	1.9			
		10.6	2.0			
		10.1	2.0			
		9.5	1.9			
		8.8	1.6			
		7.8	1.3			
		5.0	0.80			
		3.9	0.72			
		3.2	0.68			
		2.6	0.67			
		2.1	0.62			
		1.7	0.61			
		1.3	0.35			
		1.2	0.35			

Standard absolute Temperature: Tsd = 328°R Standard absolute Pressure: Psd = 29.92 in HgAbsolute Gas Temperature: Ts = 460 + Tsk = 520.5 °RAbsolute Stack Gas Pressure: Ps = Pbar + (Pg / 13.6) = 27.20 in HgStack Gas Velocity: Vs = 85.49 x Cp x [(Delta P)^{0.5}] x [Ts / (Ps x MW)]^{0.5} = _____ ft/sec

Actual Gas Flowrate: Qa = 60 x Vs x As = _____ ACFM

Average Stack Gas Dry Volumetric Flowrate: Qsd = Qa x (1 - Bws) x (Tsd / Ts) x (Ps / Psd) = _____ DSCFM

SEE
SPREAD SHEET

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EPA TEST METHOD 2

Velocity Traverse and Volumetric Flowrate Determination

Client MMR Proj. No. 5244.i3
 Facility FS-12
 City, State _____
 Test Date SEPT. 13, 1996
 Test Location Cat O₂ Inlet (6.6mm Filter)
 Test Run No. 2
 Stack Dimensions I.D. 11.294 inches Area (A_s) = 0.6957 ft²
 Static Pressure (P_g) = -36 inches H₂O
 Barometric Pressure (P_{bar}) = 29.85 inches Hg
 Stack Gas Molecular Weight (MW) = 28.81
 Stack Gas Moisture Content (Bws x 100) 1.41
 Pitot No. 160-36 C_p = 0.99
 Testers HH, WJR

Schematic of Stack / Sampling Points

TEST PORT INFORMATION / DATA

PRIMARY FLOW ELEMENT DATA

PORT	STATIC PRESS.	DEPTH inches	Delta P inches H ₂ O	T stack °F	Delta P inches H ₂ O	Comments
1B	-36	11.5	1.4	58	1.3	
		11.5	1.5			
		11.1	1.7			
		10.6	1.7			
		10.1	1.7			
		9.5	1.5			
		8.8	1.6			
		7.8	1.3			
		5.0	0.91			
		3.9	0.63			
		3.2	1.1			
		2.6	1.1			
		2.1	1.1			
		1.7	1.0			
		1.3	0.96			
		1.2	0.96			

Standard absolute Temperature: T_{std} = 528°RStandard absolute Pressure: P_{std} = 29.92 in HgAbsolute Gas Temperature: T_s = 460 + T_{sk} = 516 °RAbsolute Stack Gas Pressure: P_s = P_{bar} + (P_g / 13.6) = 27.20 in HgStack Gas Velocity: V_s = 85.49 x C_p x [(Delta P)^{0.5}] x [T_s / (P_s x MW)]^{0.5} = _____ ft/secActual Gas Flowrate: Q_a = 60 x V_s x A_s = _____ ACFMAverage Stack Gas Dry Volumetric Flowrate: Q_{sd} = Q_a x (1 - Bws) x (T_{std} / T_s) x (P_s / P_{std}) = _____ DSCFMSEE
SPREAD SHEET

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Max depth
to min

Velocity Traverse and Volumetric Flowrate Determination

○. 442

Average Stack Gas Dry Volumetric Flowrate: $Q_{sd} = Q_a \times (1 - B_{ws}) \times (T_{sd}/T_s) \times (P_s/P_{sd}) = \underline{\hspace{2cm}}$ DSCFM

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EPA TEST METHOD 2

Velocity Traverse and Volumetric Flowrate Determination

Client _____ Proj. No. _____
Facility _____
City, State _____
Test Date _____
Test Location _____
Test Run No. 2
Stack Dimensions I.D. _____ inches Area (As) = _____ ft²

Static Pressure (Pg) = _____ inches H₂O
Barometric Pressure (Pbar) = _____ inches Hg
Stack Gas Molecular Weight (MW) = _____
Stack Gas Moisture Content (Bws x 100) = _____
Pitot No. _____ Cp = _____
Testers _____

Schematic of Stack / Sampling Points

TEST PORT INFORMATION / DATA

PRIMARY FLOW ELEMENT DATA

PORT	STATIC PRESS.	DEPTH inches	Delta P inches H ₂ O	T stack °F	Delta P inches H ₂ O	Comments
13			1.4	56	1.3	
			1.5			
			1.7			
			1.7			
			1.7			
			1.5			
			1.5			
			1.3			
			3.91			
			2.63			
			1.1			
			1.1			
			1.1			
			1.0			
			0.96			
			0.96			
AVERAGE Delta P						

Standard absolute Temperature: Tsd = 528°R Standard absolute Pressure: Psd = 29.92 in Hg

Absolute Gas Temperature: Ts = 460 + Tsk = _____ °R

Absolute Stack Gas Pressure: Ps = Pbar + (Pg / 13.6) = _____ in Hg

Stack Gas Velocity: Vs = (85.49) x Cp x Delta P x cos Theta x $\frac{T_s}{(P_s \times MW)}$ = _____ ft/sec

Actual Gas Flowrate: Qa = 60 x Vs x As = _____ ACFM

Average Stack Gas Dry Volumetric Flowrate: Qsd = Qa x (1 - Bws) x (Tsd / Ts) x (Ps / Psd) = _____ DSCFM

EPA TEST METHOD 2
Velocity Traverse and Volumetric Flowrate Determination

Client _____ Proj. No. _____
Facility _____
City, State _____
Test Date _____
Test Location _____
Test Run No. 3
Stack Dimensions I.D. _____ inches Area (As) = _____ ft²

Static Pressure (Pg) = _____ inches H₂O
Barometric Pressure (Pbar) = _____ inches Hg
Stack Gas Molecular Weight (MW) = _____
Stack Gas Moisture Content (Bws x 100) = _____
Pitot No. _____ Cp = _____
Testers _____

Schematic of Stack / Sampling Points

TEST PORT INFORMATION / DATA					PRIMARY FLOW ELEMENT DATA	
PORT	STATIC PRESS.	DEPTH inches	Delta P inches H ₂ O	T stack °F	Delta P inches H ₂ O	Comments
1 G			1.4	60.5	1.3	
			1.5			
			1.7			
			1.6			
			1.6			
			1.5			
			1.3			
			1.1			
			0.96			
			1.1			
			1.2			
			1.2			
			1.3			
			1.0			
			1.0			
			1.5			
AVERAGE Delta P						

Standard absolute Temperature: Tsd = 528°R Standard absolute Pressure: Psd = 29.92 in Hg

Absolute Gas Temperature: Ts = 460 + Tsk = _____ °R

Absolute Stack Gas Pressure: Ps = Pbar + (Pg / 13.6) = _____ in Hg

Stack Gas Velocity: Vs = (85.49) x Cp x Delta P x cos Theta x $\sqrt{\frac{T_s}{(T_s \times MW)}}$ = _____ ft/sec

Actual Gas Flowrate: Qs = 60 x Vs x As = _____ ACFM

Average Stack Gas Dry Volumetric Flowrate: Qsd = Qs x (1 - Bws) x (Tsd / Ts) x (Ps / Psd) = _____ DSCFM

METHOD 2 GAS VELOCITY AND VOLUME DATA FORM

Cyclone Flow

Plant and city	Run date
ATIS	091396

Sampling location	Clock time

Run number	Operator	Amb. temp., °F	Bar. press., in. Hg	Static press., in. H ₂ O
1	H.H. BK	65°	29.85	-36" H ₂ O

Molecular wt.				Stack inside dimension, in.								Pitot tube (C _p)		
				Diam. of side 1				side 2						
												.	9	9

Field data					
<i>transverse point Angle Formula</i>					
Traverse point number	Position, in.	Velocity head (Δp), in. H ₂ O	Stack temp., °F	Cyclonic flow determination	
				Δp at 0° reference	Angle (α) which yields a null Δp
		1A 1	7	1B 1	-3
		2	8	2	10
		3	6	3	12
		4	13	4	3
		5	4	5	7
		6	3	6	15
		7	3	7	15
		8	3	8	10
		9	9	9	10
		10	10	10	8
		11	9	11	3
		12	7	12	5
		13	7	13	1
		14	4	14	0
		15	1	15	4
		16	1	16	4

Average angle (α)²

APPENDIX H

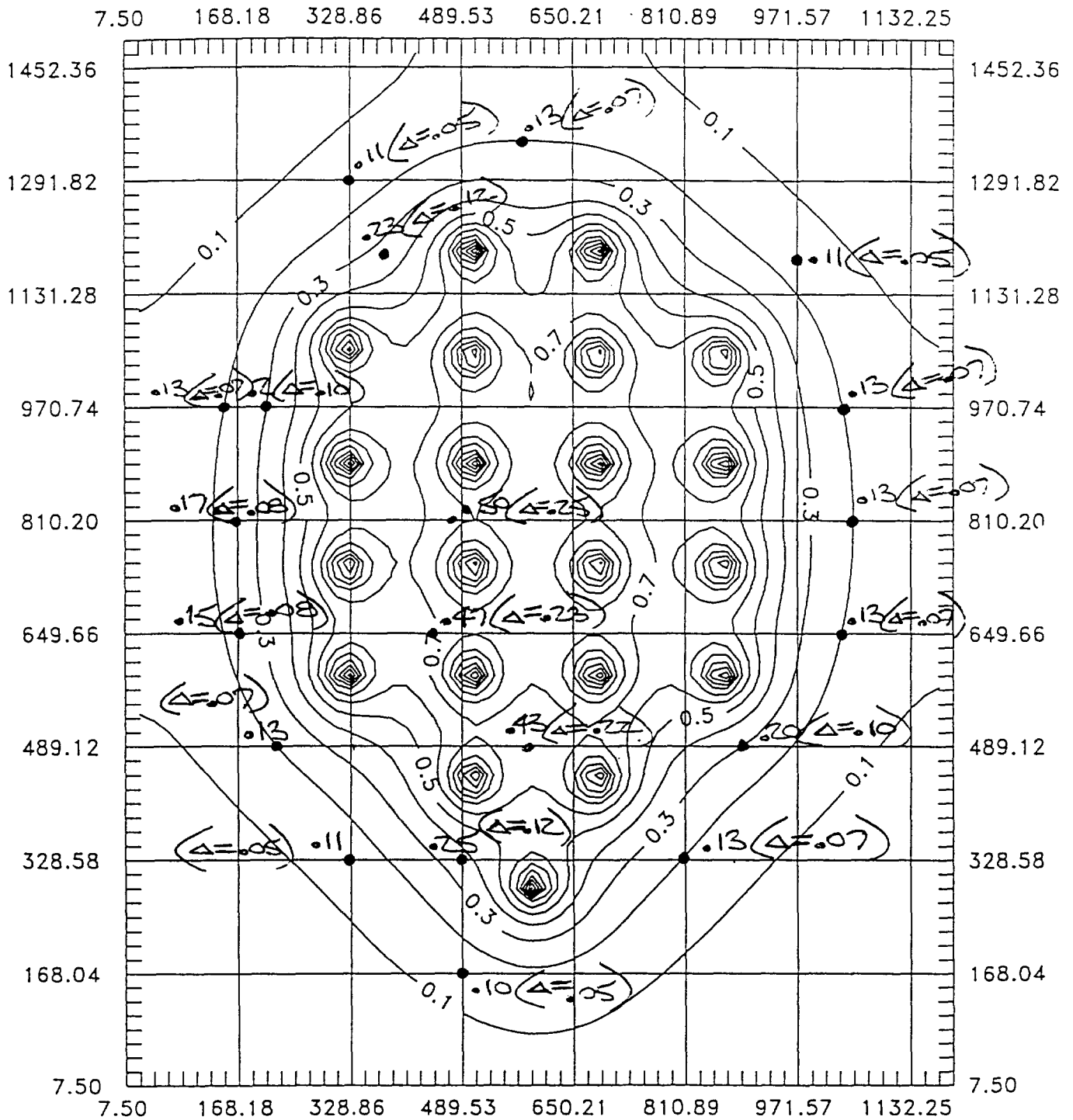
**Re-evaluation of Source Area Vacuum Pressure Distributions as a Result of
Actual SVE System Flow Rates Being Less than Design Flow Rates.**

SCENARIO 1 – SVE WELL FLOW RATE = 100 CFM FOR EACH SVE WELL

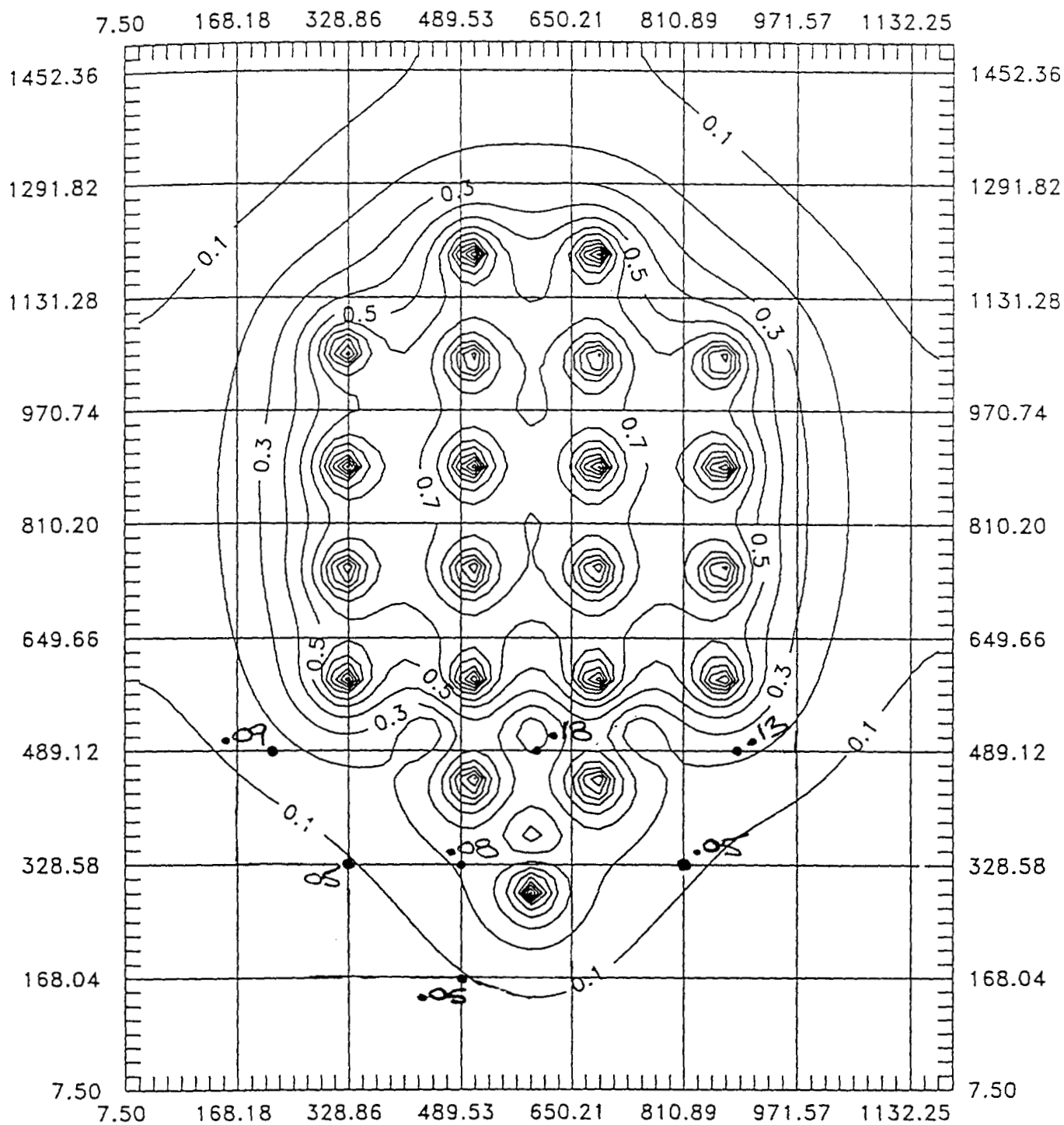
During the initial operational period of the AS/SVE system, the airflow measuring station was transmitting flow rates of approximately 2,500 actual cfm to the system computer. Project personnel and regulators raised a concern that actual operating system flow rates were less than design flow rates. The concern with the reduced flow rates is that the area of influence (or area which is maintained at a net negative pressure) will be smaller due to the reduction in per well flow rates, creating the potential for off-site migration of vapors generated as a result of the air sparging system. As a result of this concern, CAS evaluated the pressure contours generated for SVE well flow rate = 150 cfm for each SVE well, included in Section 6 of the system design calculations (ASI 1994b), to determine the impact of an average flow rate per SVE well of 100 cfm.

Assuming a linear reduction of pressure relative to flow rate, pressures shown on the pressure distribution curve (without air sparging) were reduced by 33%, and this amount was subtracted from pressures shown on the pressure distribution curves associated with operation of each leg of the air sparging system. Based on this analysis, it can be seen that although the vacuum pressures decrease within the area of influence of the sparging system, a net negative pressure is still maintained over this area of influence during operation of each leg of the air sparging system.

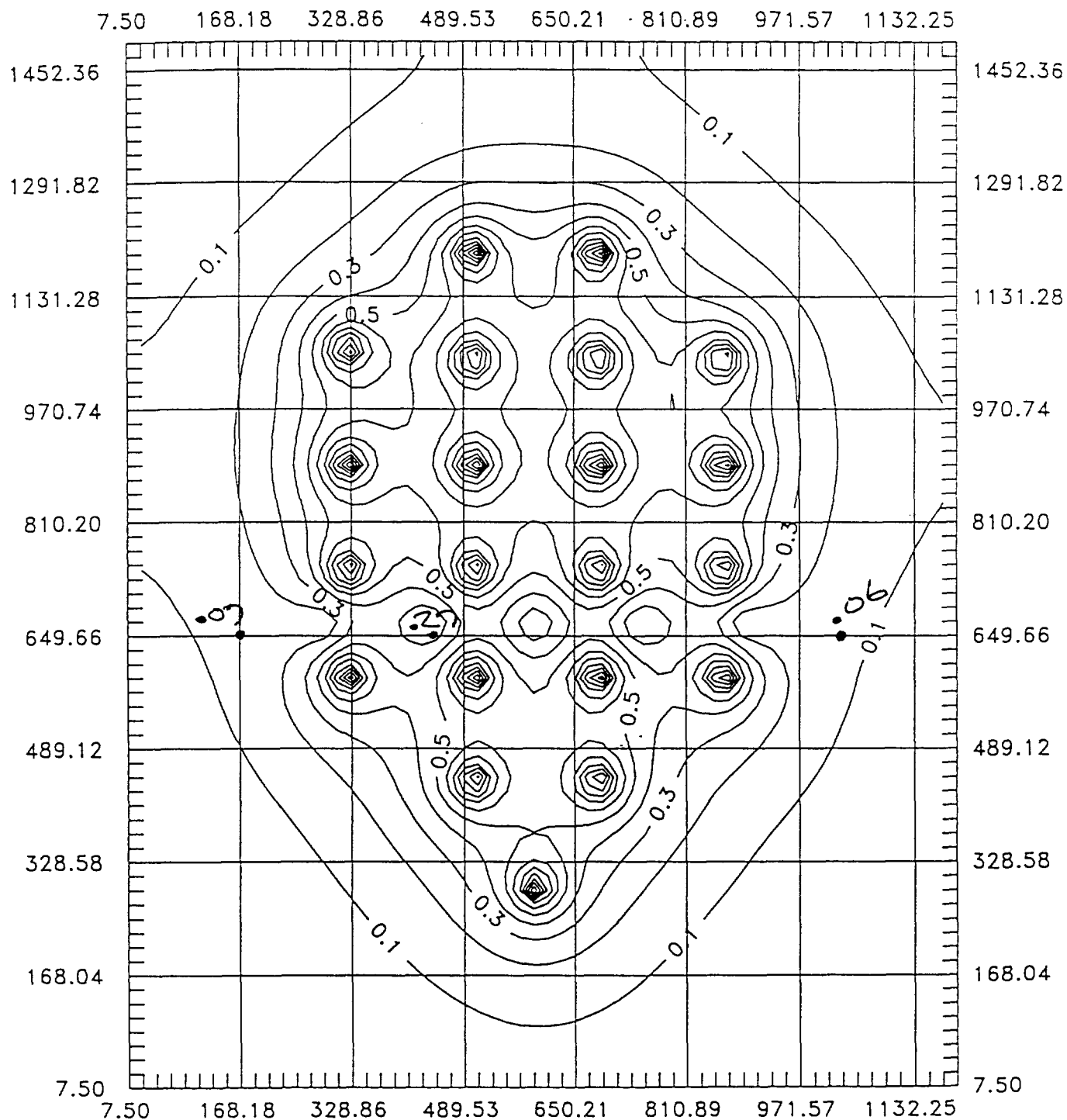
VES Pressure Dist. w/o Air Sparging



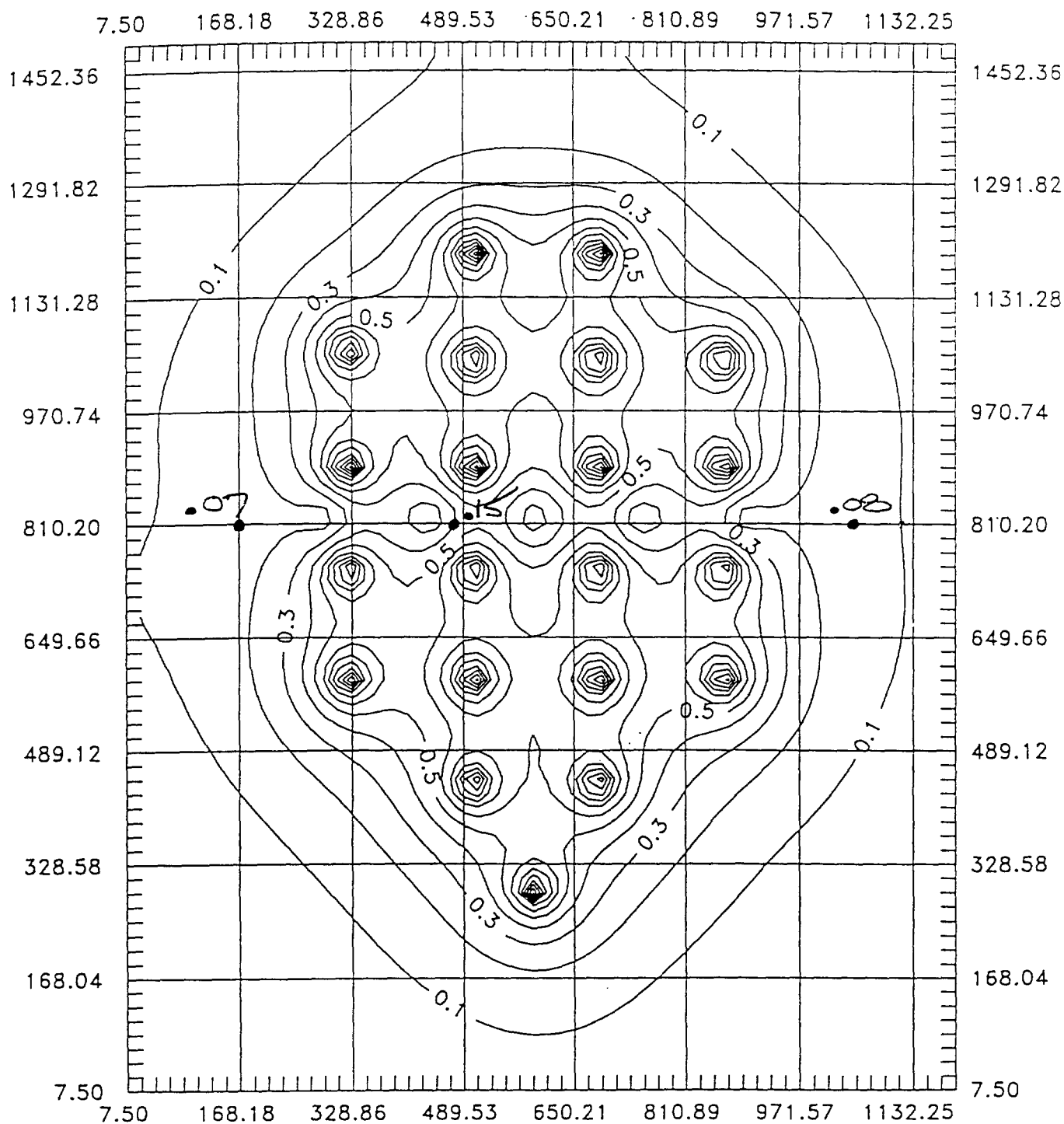
VES Pressure Dist. w/Air Sparging in Wells AS-1,2,3&4



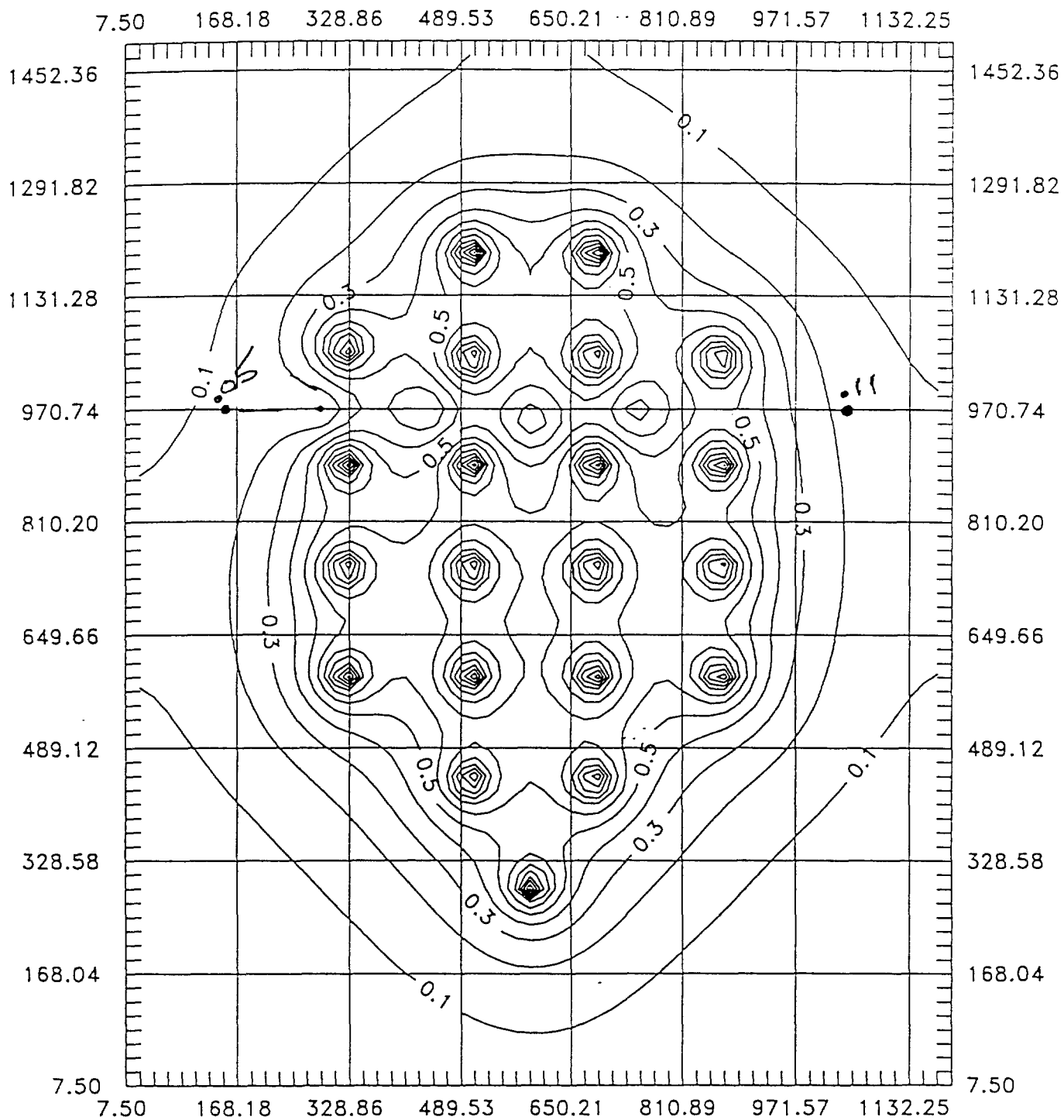
VES Pressure Dist. w/Air Sparging in Wells AS-5,6,7,8&9



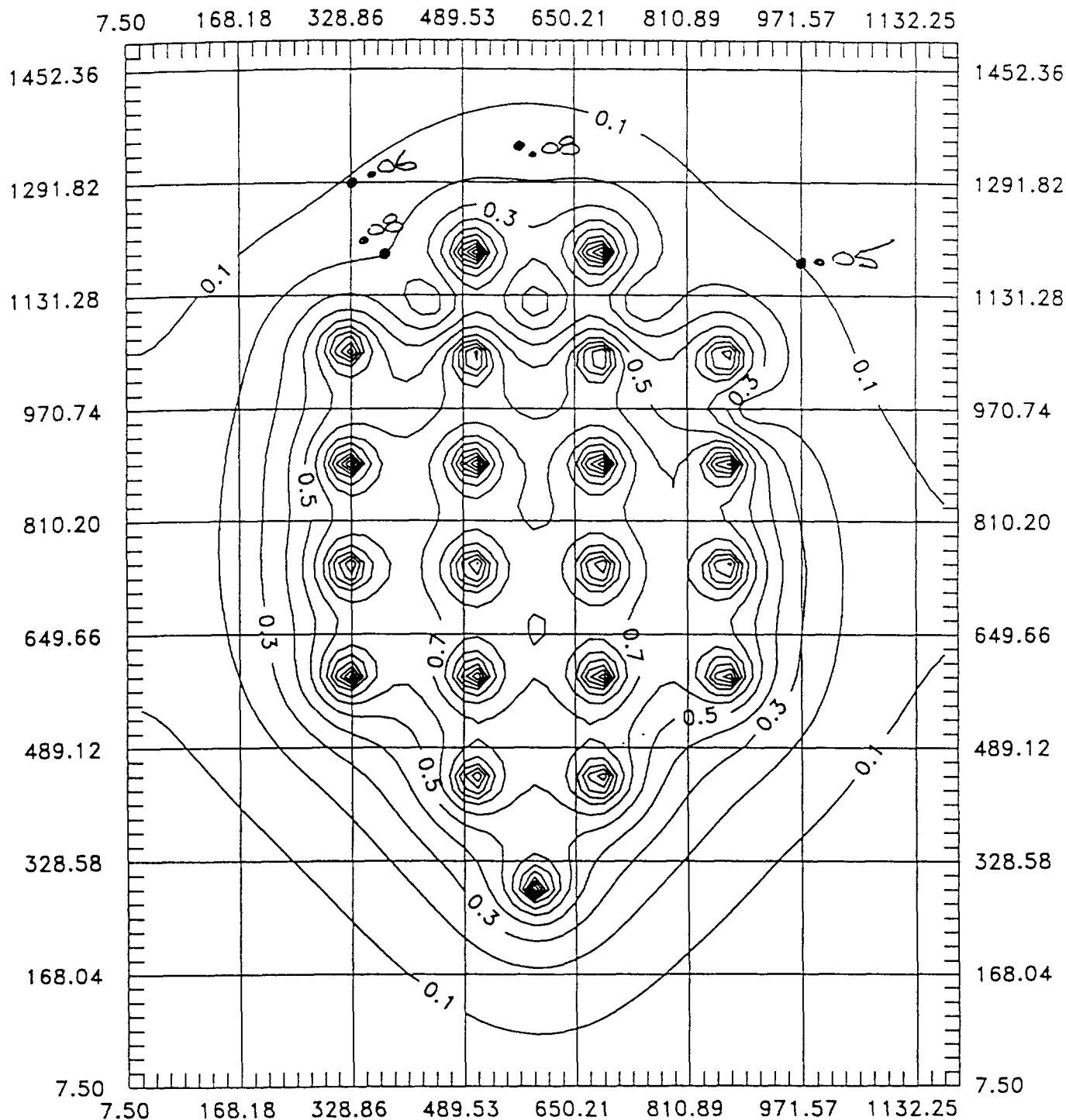
Pressure Dist. w/Air Sparging in Wells AS-10,11,12,13&14



VES Pressure Dist. w/Air Sparging in Wells AS-15,16,17,&18



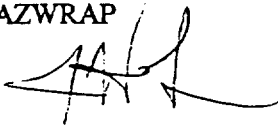
YES Pressure Dist. w/Air Sparging in Wells AS-19,20,21,&22



SCENARIO 2 – USE OF ACTUAL SVE WELL FLOW RATES MEASURED ON NOVEMBER 24, 1999

MEMORANDUM

TO: Bill Johnston, HAZWRAP

FROM: Joe Hawk, ASI 

DATE: December 11, 1997

SUBJECT: Modelling results for current operating conditions associated with the FS-12 source area remediation system (Subcontract No. FJM97C)

The purpose of this memorandum is to report the results of the recent finite difference modelling effort conducted for the FS-12 source area remediation system. The modelling was completed based on a request from the IRP office to reevaluate the system with the following changes:

- installation of new wells SV-23, SV-24, and AS-23 southwest of the originally defined source area;
- shut down of vapor extraction wells SV-20 and SV-21;
- shut down of air sparging wells AS-19, AS-20, AS-21, and AS-22; and
- new flow rates in new and existing vapor extraction wells as a result of rebalancing of the system conducted by Dave Gardner, Contractor, Inc. (Please note that flow rates used for the vapor extraction wells were measured on November 24, 1997.)

ModIME, Version 1 was used to model the new configuration for the source area remediation system. ModIME is a Modular Integrated Modeling Environment for three widely used groundwater flow, particle tracking, and solute transport models: MODFLOW (McDonald and Hargbaugh, 1988), PATH3D (Zheng, 1991), and MT3D (Zheng, 1992). ModIME allows users to prepare input data, run the model code, and postprocess the results of simulations interactively in an intuitive graphical environment. MODFLOW was used as the groundwater flow model for this exercise. Output information was imported directly into the commercial graphics package SURFER to generate plan view head distribution contours for the various operating conditions associated with the remediation system.

The attached figures represent pressure changes (relative to atmospheric pressure initially defined as zero) over the FS-12 source area at the 70-90ft. below grade interval (represents the actual average screened interval for the vapor extraction wells and is defined as Layer 3 in the model) as a result of five separate operating conditions associated with the vapor extraction/air sparging system. These operating conditions are as follows:

- Vapor extraction system fully operational without air sparging system operating;
- Vapor extraction system fully operational with air sparging wells AS-1, AS-2, AS-3, AS-4, and AS-23 operational;
- Vapor extraction system fully operational with air sparging wells AS-5, AS-6, AS-7, AS-8, and AS-9 operational;
- Vapor extraction system fully operational with air sparging wells AS-10, AS-11, AS-12, AS-13, and AS-14 operational; and
- Vapor extraction system fully operational with air sparging wells AS-15, AS-16, AS-17, and AS-18 fully operational.

Please be aware that since the sign convention (MODFLOW assumes negative flow rates indicate pumping (vapor extraction) and positive flow rates indicate injection (air sparging).) was reversed for this exercise, the positive numbers shown on the attached figures reflect negative pressure changes over the entire FS-12 source area during all five operating conditions. The flow rates used for the vapor extraction wells were measured by Dave Gardner, Contractor, Inc. (DGC, Inc.) on November 24, 1997. I conservatively assumed a flow rate of 100 cfm in each air sparging well except for new air sparging well AS-23. I assumed a flow rate of 150 cfm for this well. The air sparging well flow rates are considered conservative based on information developed by DGC, Inc. indicating actual flow rates less than 100 cfm due to possible bio-fouling and/or iron fouling in the vicinity of the microporous bubblers.

Although a net negative pressure is being maintained over the entire FS-12 source area remediation system during all five operating conditions, ASI recommends that the flow rates in vapor extraction wells SV-5, SV-8, SV-9, and SV-14 be decreased to approximately 150 cfm. ASI also recommends that flow rates in vapor extraction wells SV-15, SV-16, SV-17, SV-18, SV-19, SV-23, and SV-24 be increased to approximately 100 cfm.

If you have any questions or require additional information, please feel free to call me at (423) 483-1274.

c: Ed Pesce, IRP office
Bob Davis, IRP office
Todd Conant
Fred Crowner
Project File 9043.1.1.20.20.C

CALCULATION WORKSHEET

ORIGINATOR _____ DATE _____ SHEET ____ OF ____
 CALC. NO. _____ REV. NO. _____ DATE _____ CHECKED _____
 PROJECT _____ TASK NO. _____
 SUBJECT _____

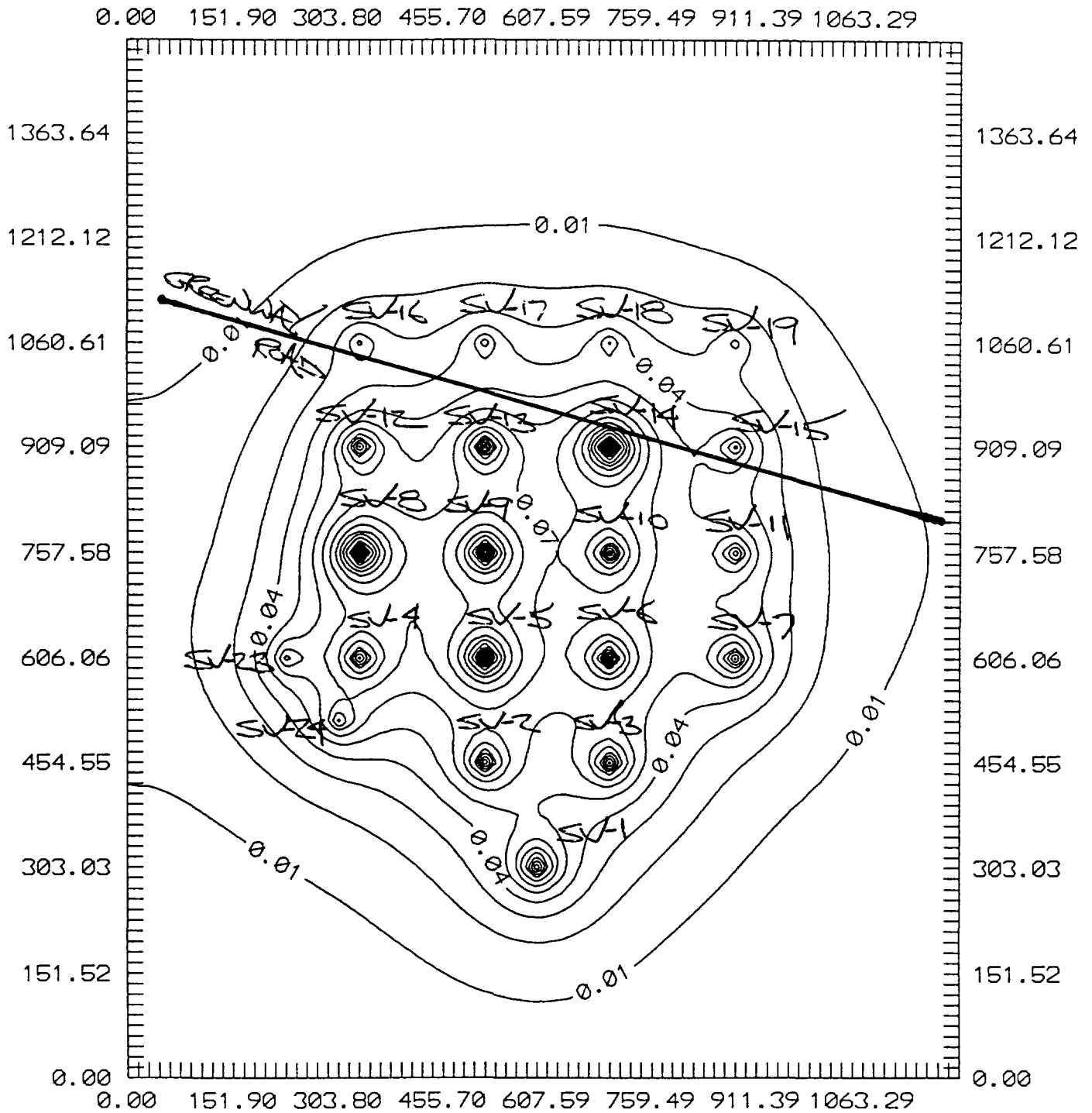
MEASURED ON 11/24/97

Flow Rate

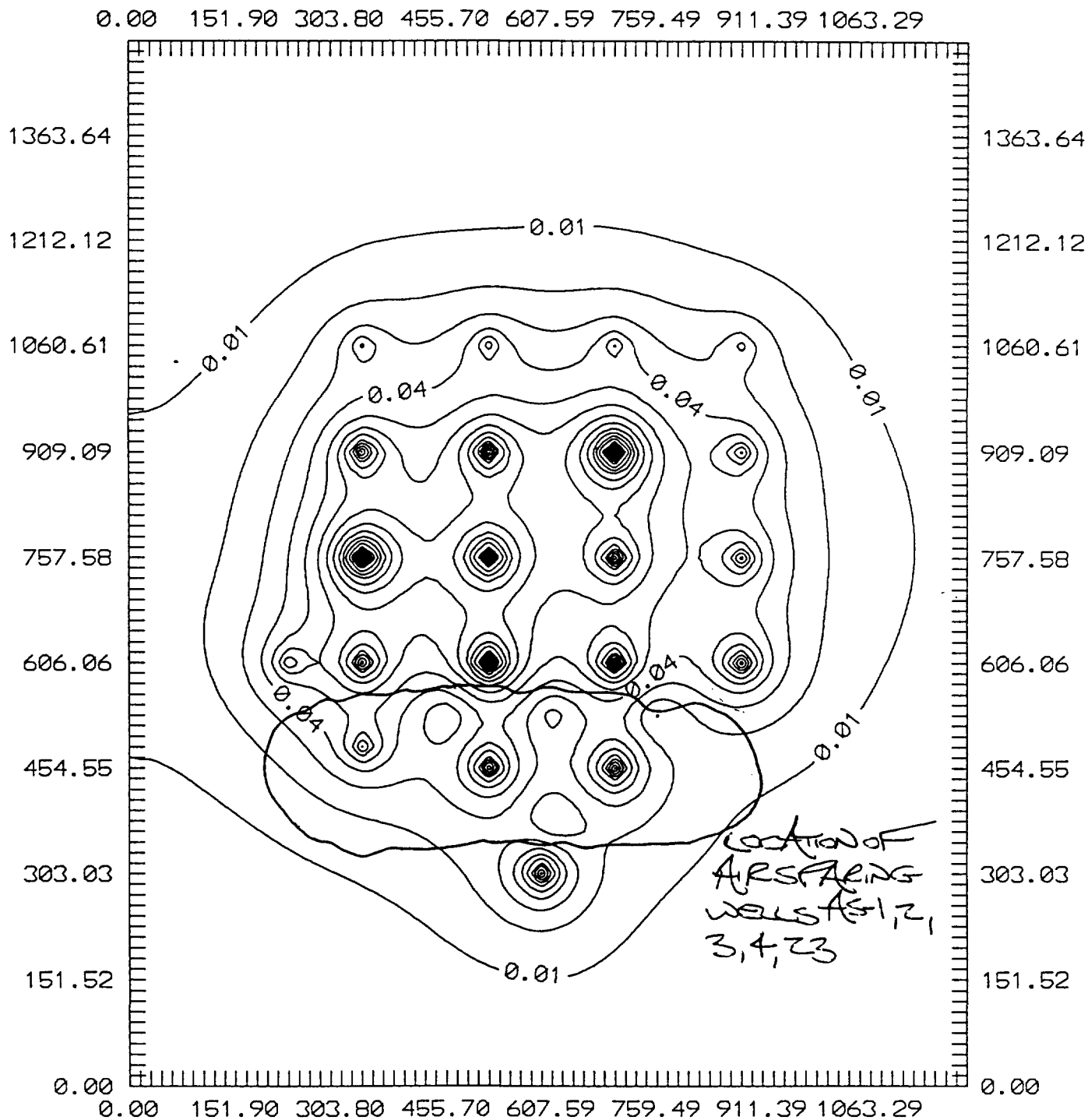
SOIL VENTING WELL	(CFM)	(CFD)
SV1	175	252,000
SV2	148	213,120
SV3	148	213,120
SV4	144	207,360
SV5	214	308,160
SV6	161	231,840
SV7	148	213,120
SV8	252	377,280
SV9	200	288,000
SV10	135	194,400
SV11	109	156,960
SV12	148	213,120
SV13	161	231,840
SV14	271	390,240
SV15	96	138,240
SV16	58	83,520
SV17	64	92,160
SV18	57	82,080
SV19	48	69,120
SV20	TURNED OFF	
SV21	TURNED OFF	
SV23	87	125,280
SV24	96	138,240
TOTAL = 2930 CFM		



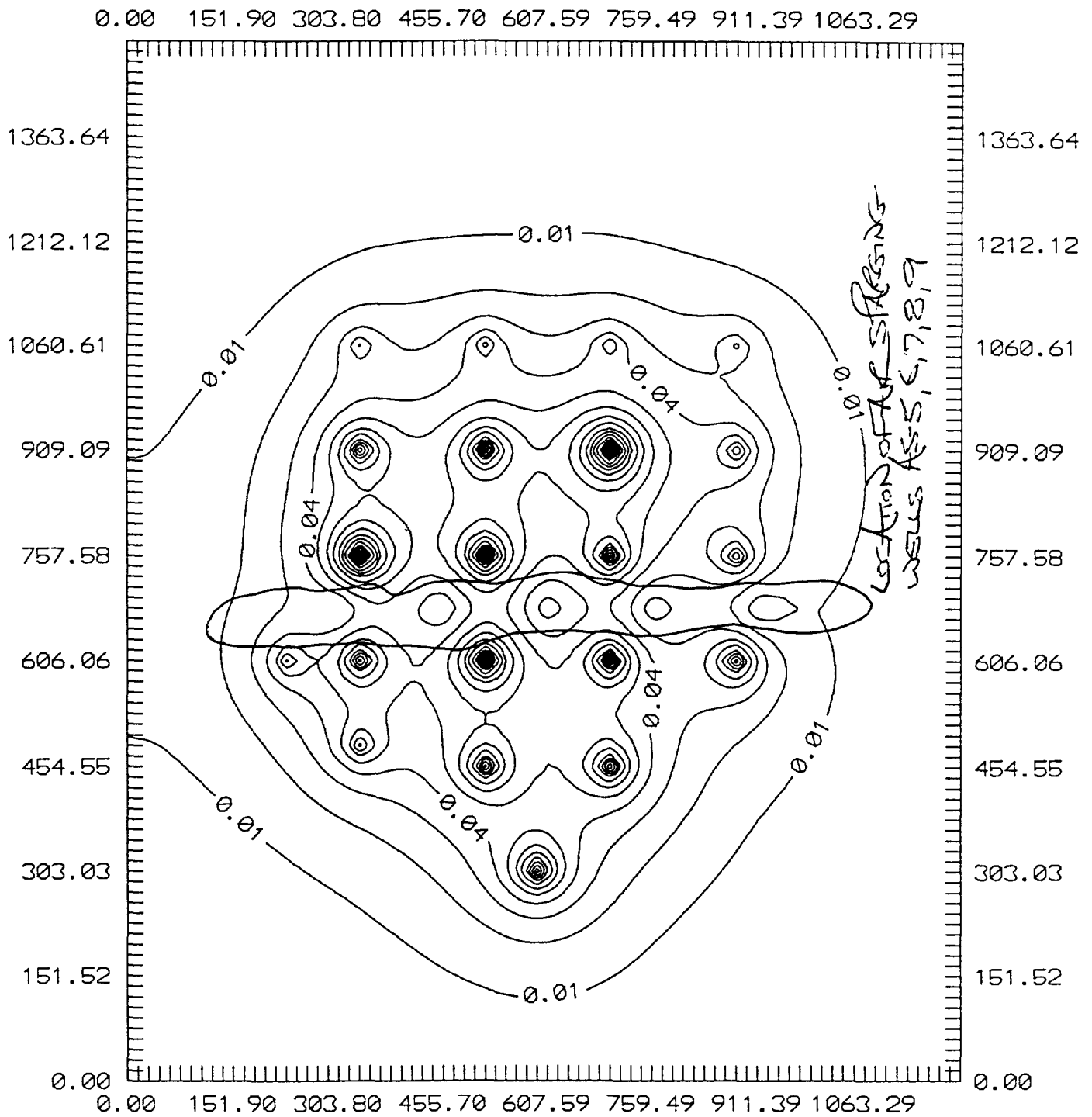
1997 VES Pressure Dist w/o Air Sparging



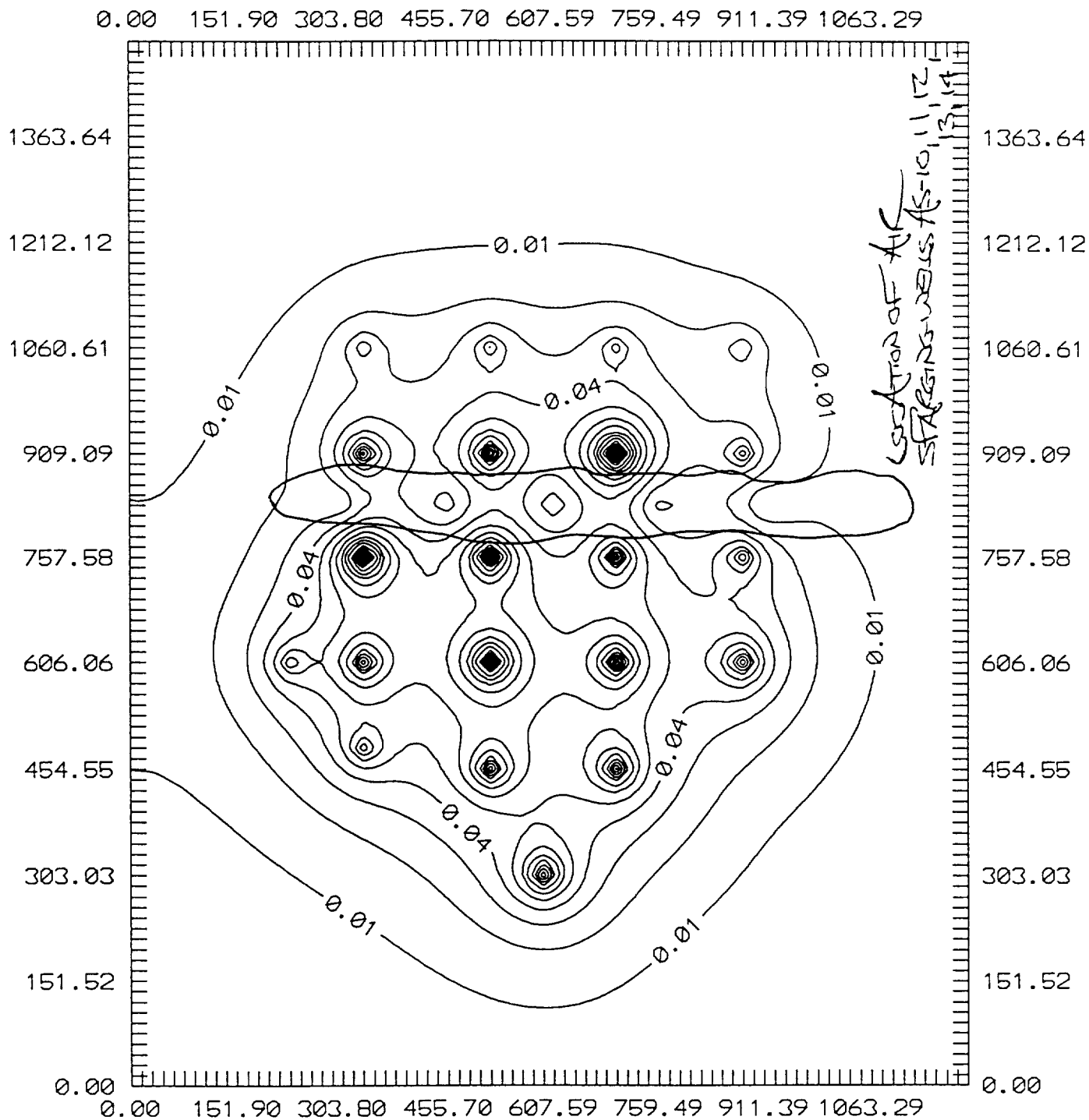
1997 VES Pressure Dist w/Air Sparging In Wells AS-1,2,3,4,23



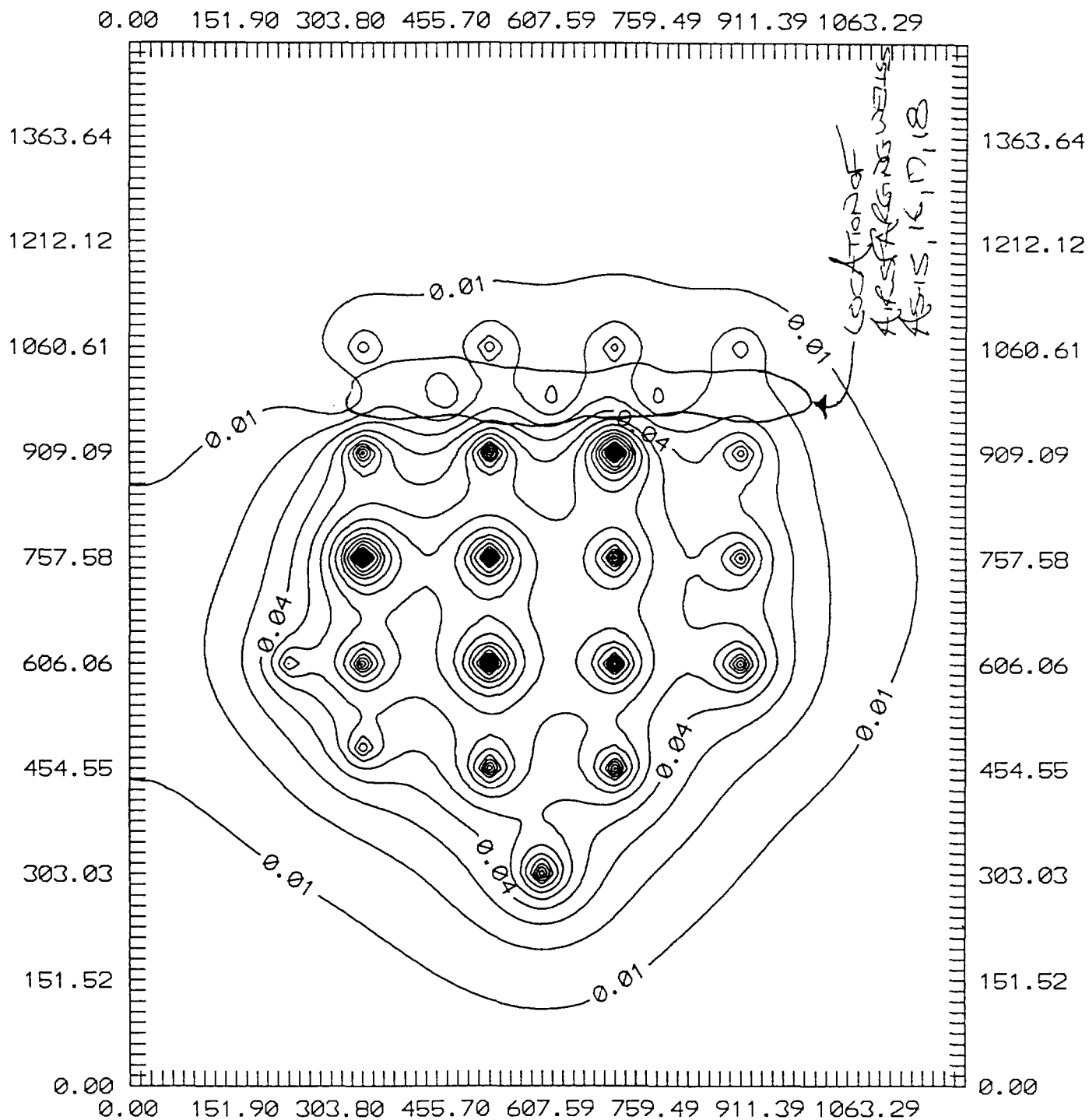
VES Pressure Dist w/air sparging in wells AS-5,6,7,8,9



VES pressure dist w/air sparging in wells AS-10,11,12,13,14



1997 VES pressure dist w/air spargling in wells AS-15,16,17,18



APPENDIX I

**Boring Logs of Soil Borings SB-1 thorough SB-10
used to Verify Site Closure
(Reference Section 8, Figure 8.1, of this Report for Boring Locations)**

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BORING NO: SB-1

page 1 of 10

Project Name: FS-12 Drilling

Project Location: FS-12 SVE/AS Site, OANGB, MA

AET Job #: 5244 20 Geologist: David M. Taylor

Contractor: Dave Gardner Assoc. Driller: DRAGIN Drilling

Drilling Method: Hollow Stem Auger Casing/Auger Size: 6.25"

Start Date: 2/10/98 Ground Elevation: N/A

Finish Date: 2/10/98 Well Elevation: N/A

BSG (feet)	Sample				PID Reading (ppm)	Time	FIELD CLASSIFICATION	Well Notes
	Type & No.	Sample Interval	Sample Recovery	Blow Count (per 6 inches)				
83'	SS	83'-85'	NA	NA	0.0	13:30p	Lt. Brown, Dry, med.-coarse Sand, trace sm. gravel	
88'	SS	88'-90'	NA	NA	0.0	13:48p	Lt. Brown, Damp, med.-coarse Sand, trace sm. gravel	
93'	SS	96'-98'	NA	NA	150	14:05p	Brown, Sat., med-coarse Sand, HC odor	
98'	SS	101'-103'	NA	NA	50	14:25p	Brown, Sat., med-coarse Sand, HC odor	
103'								

NOTES: H2O found at 93.0'. Two foot composite sample intervals taken at 10 feet and 5 feet above the water table, and 5 and 10 feet below the water level.

GRANULAR SOILS		COHESIVE SOILS		SAMPLE TYPES	PERCENTAGE
Blow Cts	Density	Blow Cts	Density		
<4	very loose	<2	very soft	SS - split spoon	and = 35-50%
5-10	loose	2-4	soft	ST - shelly tube	some = 20-35%
11-30	medium	4-8	medium stiff	AF - auger flight	little = 10 - 20%
31-50	very dense	8-15	stiff	RC - rock core	trace = 1 - 10%

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BORING NO: SB-2

page 3 of 10

Project Name: FS-12 Drilling

Project Location: FS-12 SVE/AS Site, OANGB, MA

AET Job #: 5244.20

Geologist: David M. Taylor

Contractor: Dave Gardner Assoc. Driller: DRAGIN Drilling

Drilling Method: Hollow Stem Auger Casing/Auger Size: 6.25"

Start Date: 2/11/98

Ground Elevation: N/A

Finish Date: 2/12/98

Well Elevation: N/A

BSG (feet)	Sample				PID Reading (ppm)	Time	FIELD CLASSIFICATION	Well Notes
	Type & No.	Sample Interval	Sample Recovery	Blow Count (per 6 inches)				
82'								
	82'-84'	1	NA	NA	0.0	12:30p	Lt. Brown, Dry, med.-coarse Sand	
87'								
	87'-89'	2	NA	NA	0.0	12:48p	Lt. Brown, Damp, med.-coarse Sand, trace sm. gravel	
92'								
	95'-97'	3	NA	NA	2.5	13:05p	Brown, Sat., fine to med Sand, little sm. grav.	
97'								
	97'-103'	4	NA	NA	18.5	09:25p	Brown, Sat., fine to med. Sand, little sm. grav.	
103'								

NOTES: H2O found at 92.3'. Two foot composite sample intervals taken at 10 feet and 5 feet above the water table, and 5 and 10 feet below the water level. Straight sampling with the two foot split spoon was initiated at 97 feet and will continue with the remaining sampling activities .

GRANULAR SOILS		COHESIVE SOILS		SAMPLE TYPES	PERCENTAGE and = 35-50% some = 20-35% little = 10 - 20% trace = 1 - 10%
Blow Cts	Density	Blow Cts	Density		
<4	very loose	<2	very soft	SS - split spoon	
5-10	loose	2-4	soft	ST - Shelby tube	
11-30	medium	4-8	medium stiff	AF - auger flight	
31-50	very dense	8-15	stiff	RC - rock core	

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BORING NO: **SB-3**

page 4 of 10

Project Name: FS-12 Drilling

Project Location: FS-12 SVE/AS Site, OANGB, MA

AET Job #: 5244.20

Geologist: David M. Taylor

Contractor: Dave Gardner Assoc.

Driller: DRAGIN Drilling

Drilling Method: Hollow Stem Auger Casing/Auger Size: 6.25"

Start Date: 2/12/98

Ground Elevation: N/A

Finish Date: 2/13/98

Well Elevation: N/A

BSG (feet)	Sample				PID Reading (ppm)	Time	FIELD CLASSIFICATION	Well Notes
	Type & No.	Sample Interval	Sample Recovery	Blow Count (per 6 inches)				
78'					0.0	13:10p	Lt. Brown, Dry, fine-coarse Sand, trace sm. gravel	
	78'-83'	1	NA	NA				
83'					0.0	13:42p	Lt. Brown, Damp, med.-coarse Sand, trace sm. gravel	
	83'-88'	2	NA	NA				
88'					0.0	14:05p	Lt. Brown, Sat., med-coarse Sand	
	88'-93'	3	NA	NA				
93'					0.0	09:25p	Brownish Grey, Sat., fine-coarse Sand, tr. sm. grav.	
	93'-98'	4	NA	NA				
98'								

NOTES: H2O found at 87.7'. Two foot split spoons were used to make up the 5 foot composite intervals taken from 10 feet above to 10 feet below the water table.

GRANULAR SOILS
Blow Cts Density
<4 very loose
5-10 loose
11-30 medium
31-50 very dense

COHESIVE SOILS
Blow Cts Density
<2 very soft
2-4 soft
4-8 medium stiff
8-15 stiff

SAMPLE TYPES
SS - split spoon
ST - Shelby tube
AF - auger flight
RC - rock core

PERCENTAGE
and = 35-50%
some = 20-35%
little = 10 - 20%
trace = 1 - 10%

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BORING NO: SB-4

page 2 of 10

Project Name: FS-12 Drilling

Project Location: FS-12 SVE/AS Site, OANGB, MA

AET Job #: 5244.20

Geologist: David M. Taylor

Contractor: Dave Gardner Assoc. Driller: DRAGIN Drilling

Drilling Method: Hollow Stem Auger Casing/Auger Size: 6.25"

Start Date: 2/11/98

Ground Elevation: N/A

Finish Date: 2/11/98

Well Elevation: N/A

BSG (feet)	Sample				PID Reading (ppm)	Time	FIELD CLASSIFICATION	Well Notes
	Type & No.	Sample Interval	Sample Recovery	Blow Count (per 6 inches)				
81'					0.0	9:30p	Lt. Brown, Dry, med.-coarse Sand	
86'	SS	81'-83'	NA	NA	1.0	9:48p	Lt. Brown, Dry, med.-coarse Sand, some fines	
91'	SS	86'-88'	NA	NA	0.5	10:05p	Brown, Sat., med-coarse Sand, HC odor	
96'	SS	94'-96'	NA	NA	1.5	10:25p	Brown, Sat., med-coarse Sand, HC odor	
101'								

NOTES: H₂O found at 90.6'. Two foot composite sample intervals taken at 10 feet and 5 feet above the water table, and 5 and 10 feet below the water level.

GRANULAR SOILS		COHESIVE SOILS		SAMPLE TYPES	PERCENTAGE
Blow Cts	Density	Blow Cts	Density		
<4	very loose	<2	very soft	SS - split spoon	and = 33-50%
5-10	loose	2-4	soft	ST - Shelby tube	some = 20-35%
11-30	medium	4-8	medium stiff	AF - auger flight	little = 10 - 20%
31-50	very dense	8-15	stiff	RC - rock core	trace = 1 - 10%

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BORING NO: SB-5

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Project Name: FS-12 Drilling

Project Location: FS-12 SVE/AS Site, OANGB, MA

AET Job #: 5244.20

Geologist: David M. Taylor

Contractor: Dave Gardner Assoc. Driller: DRAGIN Drilling

Drilling Method: Hollow Stem Auger Casing/Auger Size: 6.25"

Start Date: 2/13/98

Ground Elevation: N/A

Finish Date: 2/13/98

Well Elevation: N/A

BSG (feet)	Sample				PID Reading (ppm)	Time	FIELD CLASSIFICATION	Well Notes
	Type & No.	Sample Interval	Sample Recovery	Blow Count (per 6 inches)				
81'								
	81'-86'	1	NA	NA	10	10:30p	Lt. Brown, dry, fine to med. Sand, tr. sm. Grav.	
86'								
	86'-91'	2	NA	NA	35	10:48p	Lt. Brown, damp, fine to med. Sand	
91'								
	91'-96'	3	NA	NA	170	11:05p	Lt. Brown, Sat., fine-coarse Sand, HC Odor	
96'								
	96'-101'	4	NA	NA	300	11:25p	Lt. Brown, Sat., fine-coarse Sand, HC Odor	
101'								

NOTES: H2O found at 90.7'. Two foot split spoons were used to make up the 5 foot composite intervals taken from 10 feet above to 10 feet below the water table.

GRANULAR SOILS	COHESIVE SOILS	SAMPLE TYPES	PERCENTAGE
Blow Cts Density	Blow Cts Density	SS - split spoon	and = 35-50%
<4 very loose	<2 very soft	ST - shelly tube	some = 20-35%
5-10 loose	2-4 soft	AF - auger flight	little = 10 - 20%
11-30 medium	4-8 medium stiff	RC - rock core	trace = 1 - 10%
31-50 very dense	8-15 stiff		

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BORING NO: SB-6

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Project Name: FS-12 Drilling

Project Location: FS-12 SVE/AS Site, OANGB, MA

AET Job #: 5244.20 Geologist: David M. Taylor

Contractor: Dave Gardner Assoc. Driller: DRAGIN Drilling

Drilling Method: Hollow Stem Auger Casing/Auger Size: 6.25"

Start Date: 2/13/98 Ground Elevation: N/A

Finish Date: 2/16/98 Well Elevation: N/A

BSG (feet)	Sample				PID Reading (ppm)	Time	FIELD CLASSIFICATION	Well Notes
	Type & No.	Sample Interval	Sample Recovery	Blow Count (per 6 inches)				
79'								
	79'-84'	1	NA	NA	10	13:30p	Lt. Brown, Dry, fine to med. Sand, trace sm. gravel	
84'								
	84'-89'	2	NA	NA	3	13:48p	Lt. Brown, Damp, med.-coarse Sand, trace sm. gravel	
89'								
	89'-94'	3	NA	NA	4.5	14:05p	Lt. Brown, Sat., med-coarse Sand	
94'								
	94'-99'	4	NA	NA	300	14:25p	Lt. Brown, Sat., fine to med Sand, HC odor	
99'								

NOTES: H2O found at 89.5'. Two foot split spoons were used to make up the 5 foot composite intervals taken from 10 feet above to 10 feet below the water table.

GRANULAR SOILS		COHESIVE SOILS		SAMPLE TYPES	PERCENTAGE and = 35-50% some = 20-35% little = 10 - 20% trace = 1 - 10%
Blow Cts	Density	Blow Cts	Density		
<4	very loose	<2	very soft	SS - split spoon	
5-10	loose	2-4	soft	ST - Shelby tube	
11-30	medium	4-8	medium stiff	AF - auger flight	
31-50	very dense	8-15	stiff	RC - rock core	

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BORING NO: SB-7

page 7 of 10

Project Name: FS-12 Drilling

Project Location: FS-12 SVE/AS Site, OANGB, MA

AET Job #: 5244.20

Geologist: David M. Taylor

Contractor: Dave Gardner Assoc.

Driller: DRAGIN Drilling

Drilling Method: Hollow Stem Auger Casing/Auger Size: 6.25"

Start Date: 2/16/98

Ground Elevation: N/A

Finish Date: 2/16/98

Well Elevation: N/A

BSG (feet)	Sample				PID Reading (ppm)	Time	FIELD CLASSIFICATION	Well Notes
	Type & No.	Sample Interval	Sample Recovery	Blow Count (per 6 inches)				
78'								
	78'-83'	1	NA	NA	10	10:30p	Lt. Brown, Dry, fine to med. Sand	
83'								
	83'-88'	2	NA	NA	3	10:48p	Lt. Brown, Dry, fine to med. Sand	
88'								
	88'-93'	3	NA	NA	150	11:05p	Lt. Brown, Wet., fine to med. Sand, HC odor	
93'								
	93'-98'	4	NA	NA	350	12:25p	Lt. Brown, Sat., fine to med. Sand, HC odor	
98'								

NOTES: H2O found at 88.5'. Two foot split spoons were used to make up the 5 foot composite intervals taken from 10 feet above to 10 feet below the water table.

GRANULAR SOILS
Blow Cts Density
<4 very loose
5-10 loose
11-30 medium
31-50 very dense

COHESIVE SOILS
Blow Cts Density
<4 very soft
2-4 soft
4-8 medium stiff
8-15 stiff

SAMPLE TYPES
SS - split spoon
ST - shelly tube
AF - auger flight
RC - rock core

PERCENTAGE
and = 35-50%
some = 20-35%
little = 10 - 20%
trace = 1 - 10%

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BORING NO: SB-8

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Project Name: FS-12 Drilling

Project Location: FS-12 SVE/AS Site, OANGB, MA

AET Job #: 5244.20

Geologist: David M. Taylor

Contractor: Dave Gardner Assoc. Driller: DRAGIN Drilling

Drilling Method: Hollow Stem Auger Casing/Auger Size: 4.25"

Start Date: 2/19/98

Ground Elevation: N/A

Finish Date: 2/19/98

Well Elevation: N/A

BSG (feet)	Sample				PID Reading (ppm)	Time	FIELD CLASSIFICATION	Well Notes
	Type & No.	Sample Interval	Sample Recovery	Blow Count (per 6 inches)				
78'					0.0	9:30p	Lt. Brown, moist, med.-coarse Sand, trace sm. gravel	
83'	78-83'	1	NA	NA	0.0	9:48p	Lt. Brown, damp, med.-coarse Sand, trace sm. gravel	
88'	83-88'	2	NA	NA	0.0	10:05p	Brown, Sat., med-coarse Sand	
93'	88-93'	3	NA	NA	0.0	10:25p	Brown, Sat., med-coarse Sand	
98'	93-98'	4	NA	NA				

NOTES: H2O found at 87.9'. Two foot split spoons were used to make up the 5 foot composite intervals taken from 10 feet above to 10 feet below the water table.

GRANULAR SOILS		COHESIVE SOILS		SAMPLE TYPES	PERCENTAGE
Blow Cts	Density	Blow Cts	Density		
<4	very loose	<2	very soft	SS - split spoon	and = 35-50%
5-10	loose	2-4	soft	ST - Shelby tube	some = 20-35%
11-30	medium	4-8	medium stiff	AF - auger flight	little = 10 - 20%
31-50	very dense	8-15	stiff	RC - rock core	trace = 1 - 10%

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BORING NO: SB-9

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Project Name: FS-12 Drilling

Project Location: FS-12 SVE/AS Site, OANGB, MA

AET Job #: 5244.20

Geologist: David M. Taylor

Contractor: Dave Gardner Assoc. Driller: DRAGIN Drilling

Drilling Method: Hollow Stem Auger Casing/Auger Size: 4.25"

Start Date: 2/19/98

Ground Elevation: N/A

Finish Date: 2/19/98

Well Elevation: N/A

BSG (feet)	Sample				PID Reading (ppm)	Time	FIELD CLASSIFICATION	Well Notes
	Type & No.	Sample Interval	Sample Recovery	Blow Count (per 6 inches)				
75'								
	75-80'	1	NA	NA	0.0	15:30p	Brown, damp, med.-coarse Sand, trace sm.-med. gravel	
80'								
	80-85'	2	NA	NA	0.0	15:48p	Brown, moist, med.-coarse Sand, trace sm.-med. gravel	
85'								
	85-90'	3	NA	NA	0.0	16:05p	Brown, Sat., med-coarse Sand,	
90'								
	99-95'	4	NA	NA	0.0	16:25p	Brown, Sat., med-coarse Sand,	
95'								

NOTES: H2O found at 85.0'. Two foot split spoons were used to make up the 5 foot composite intervals taken from 10 feet above to 10 feet below the water table.

GRANULAR SOILS
Blow Cts Density
<4 very loose
5-10 loose
11-30 medium
31-50 very dense

COHESIVE SOILS
Blow Cts Density
<2 very soft
2-4 soft
4-8 medium stiff
8-15 stiff

SAMPLE TYPES
SS - split spoon
ST - shelby tube
AF - auger flight
RC - rock core

PERCENTAGE
and = 35-50%
some = 20-35%
little = 10 - 20%
trace = 1 - 10%

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BORING NO: SB-10

page 10 of 10

Project Name: FS-12 Drilling

Project Location: FS-12 SVE/AS Site, OANGB, MA

AET Job #: 5244.20 Geologist: David M. Taylor

Contractor: Dave Gardner Assoc. Driller: DRAGIN Drilling

Drilling Method: Hollow Stem Auger Casing/Auger Size: 4.25"

Start Date: 2/20/98 Ground Elevation: N/A

Finish Date: 2/20/98 Well Elevation: N/A

BSG (feet)	Sample				PID Reading (ppm)	Time	FIELD CLASSIFICATION	Well Notes
	Type & No.	Sample Interval	Sample Recovery	Blow Count (per 6 inches)				
77'								
	78-83'	1	NA	NA	0.0	9:30p	Lt. Brown, damp, med.-coarse Sand	
82'								
	83-88'	2	NA	NA	0.0	9:58p	Lt. Brown, moist, med.-coarse Sand	
87'								
	88-93'	3	NA	NA	0.0	10:05p	Brown, wet.. med-coarse Sand, tr. small gravel	
92'								
	93-98'	4	NA	NA	0.0	10:25p	Brown, Sat., med-coarse Sand, tr. small gravel	
97'								

NOTES: H2O found at 87.0'. Two foot split spoons were used to make up the 5 foot composite intervals taken from 10 feet above to 10 feet below the water table.

GRANULAR SOILS
Blow Cts Density
<4 very loose
5-10 loose
11-30 medium
31-50 very dense

COHESIVE SOILS
Blow Cts Density
<2 very soft
2-4 soft
4-8 medium stiff
8-15 stiff


SAMPLE TYPES
SS - split spoon
ST - shelly tube
AF - auger flight
RC - rock core

PERCENTAGE
and = 35-50%
some = 20-35%
little = 10 - 20%
trace = 1 - 10%

APPENDIX J

**Unitech Memo to AFC EE, Subject: Estimation of Free Product
at Source Area of FS-12, dated September 8, 1998.**

Memo

To: FS-12 File, AFCEE
From: Carter Fahy 
CC: Spence Smith, AFCEE
Date: 09/08/98
Re: Estimation of Free Product at Source Area of FS-12

Purpose/Background: On February 25, 1998, the Air Sparging/Soil Vapor Extraction system operating at the source area of FS-12 was shut down and demobilized due to the low amount of contaminants being recovered. From the system's start-up on October 23, 1995 until its shutdown, 20,217 Kg of VOC Contamination was recovered (Atlantic Env. Tech., Inc., Monthly Report #29). Previous estimates in 1993, had estimated the volume of product (aviation gasoline/jet fuel) at the source area to be approximately 71,000 gallons (189,000 kg using a specific gravity of 0.7 for aviation gasoline/jet fuel). With just over 10% of the estimated original volume recovered by the AS/SVE system, the question is "where is the other 90%?" This memo details/critiques the efforts initially made in 1993 to estimate the volume of product at the source area.

Jan/Feb 1993 – FS-12 Free Product Gauging (HAZWRAP RI REPORT, FS-12 STUDY AREA, VOLUME III, APPENDIX G, Jan/1995): Advanced Sciences, Inc. (ASI), under contract to HAZWRAP installed nine monitoring wells at the FS-12 Source Area in January/February, 1993 in order to define the extent of free product. After installation, several water level/product thickness measurements were made of each well. Product thickness was measured using product gauging paste. The tabulated product thicknesses are attached. As indicated in the attached table, the groundwater table fluctuated as much as six inches during this period (1/21/93-2/17/93). In several of the wells (LWA-2, LWA-5, WT-13), the product thickness varied inversely with the groundwater table height (i.e., as the groundwater table decreased, the product thickness increased, and vice versa), indicating a "capillary effect" (exaggeration of product thickness). This "effect" was not explained in ASI's conclusions.

May, 1993 – FS-12 Free Product Recovery Modeling (HAZWRAP RI REPORT, FS-12 STUDY AREA, VOLUME III, APPENDIX G, Jan/1995): Using the thickest product measurements from each of the wells measured in Jan/Feb '93, ASI used the software packages SPILLCAD and ARMOS-Lite to model the free product at the source area. Several parameters in addition to product thickness were needed to accurately estimate the volume of product. Of these parameters, only hydraulic conductivity, porosity, and specific yield were based on field data. The remaining parameters (most critically, mean pore size) were estimated by SPILLCAD based on field data. The model produced nine volume estimates as the range of input parameters changed. The prediction of total oil volume varied: (a) from 4,400 to 71,000 gallons with a variation of mean pore size (4.5 to 23.7), (b) from 57,000 to 85,000 gallons with a variation of pore size distribution (2.0 to 5.0), and (c) from 52,000 to 93,000 gallons with change of product type (#2 oil to gasoline). In concluding their modeling report, ASI recommended that

the mean pore size of the source area be calibrated with field data collected during Product Recovery pilot studies in order to improve the accuracy of the product volume calculations.

September, 1993: FS-12 Product Recovery Pilot Study (ASI REPORT OF AIR SPARGING, SOIL VAPOR EXTRACTION, AND PRODUCT RECOVERY PILOT STUDIES CONDUCTED AT THE FS-12 SOURCE AREA, VOL III, 3/94): In this 7-day study, a groundwater/product recovery system was operated to determine the efficacy of product recovery at the source area. During the entire pilot study, floating product was not detected or recovered in the one product recovery well. Only one (LWA-1) of the six monitoring wells where measurable product thickness was observed in Jan/Feb, 1993, had measurable product thickness during this pilot study. The groundwater levels were approximately three feet higher at the time the pilot study was conducted. Groundwater levels were at historic lows during the December, 1992, time frame. ASI's explanation of this product thickness difference was that there was "smearing of the product as the water table rose, leaving a zone of contaminated soil below the water table and no product remaining on top of the water table." The pilot study report did not contain any analysis of the mean pore size of the source area as recommended in ASI's previous reports. No re-estimation of the product volume at the source area was given.

August, 1994, Product Measurement: The product levels in 16 monitoring wells at the source area were measured. Only two wells, LWA-1, and LWA-3 had measurable product thicknesses (6", 7" respectively).

Summary/Conclusions: The volume of product at the source area estimated by SPILLCAD varied from 4,400 – 93,000 gallons. These estimates were based, in large part, on the product thickness measured in Jan-Feb, '93, where 6 wells had measurable product thicknesses. The thicknesses were probably overestimated due to a combination of historically low groundwater levels at the time and the product/groundwater table capillary effect observed. The overall thickness of product in the wells was not observed in 2 successive measurements (9/93, 10/94). Key input data for the SPILLCAD model estimate was missing (pore size, pore size distribution) and was not collected during the pilot study. The selection of 71,000 gallons as the volume estimate was never fully explained in ASI's May '93 report other than it was the model's volume estimate in 3 of the 9 scenarios. In the 6 other scenarios, no other volume estimate showed up more than once. No recalculation of the 71,000 gallon estimate was conducted based on information gained during subsequent measurements, the product recovery pilot study, or during the operation of the AS/SVE system. Based on subsequent measurements, and the amount of product recovered by the AS/SVE system from 1993-1995, the estimate of 71,000 gallons appears to be significantly inflated.

Footnote: The volume of product recovered to date by the FS-12 groundwater recovery wells was not included when calculating the amount recovered to date from the 71,000 gallons. When the 71,000-gallon figure was calculated, ASI was specifically looking at the 11-acre source area where free product was detected, not the rest of the plume which had already migrated downgradient from this area. According to recent Jacob's Engineering modeling data, contaminants currently located in the source area will take 5-6 years to migrate to the northernmost groundwater recovery well. Therefore, contaminants measured in Jan/Feb 1993 would just be reaching the northernmost recovery wells this year (1998). It will probably be slower than that because the AS/SVE system was operational during that period.

Attached: Selected pages from the referenced documents.

APPENDIX K

**Letter (with attachments) from AFCEE to EPA/MA DEP,
Subject: Shutdown of Catalytic Oxidation Unit
at FS-12 Source Remediation System.**



**DEPARTMENT OF THE AIR FORCE
HEADQUARTERS AIR FORCE CENTER FOR ENVIRONMENTAL EXCELLENCE
INSTALLATION RESTORATION PROGRAM
OTIS AIR NATIONAL GUARD BASE, MA 02542-5028**

2 July 97

HQ AFCEE/MMR
322 East Inner Road Box 41
Otis ANG Base, MA. 02542

Mr. Paul Marchessault
USEPA-HAN/CANI
JFK Federal Building
Boston, MA. 02203

Mr. Len Pinaud
MADEP- Southeast Region
20 Riverside Drive
Lakeville, MA. 02347

SUBJECT: Shut Down of Catalytic Oxydizer Unit at FS-12 Source Remediation System.

Gentlemen

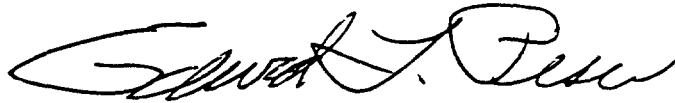
The purpose of this letter is to provide a "memorandum for the record" relative to the shut down of the catalytic oxydizer at the FS-12 Air Sparging and Soil Venting System. As you are aware, the catalytic oxydizer was shut down on 13 June, 1997. Prior to the shut down date, Mr. Dave Gardner, the contractor for the project, requested in writing (letter dated 27 May) to the U.S. Environmental Protection Agency and the MA. Department of Environmental Protection, that the catalytic oxydizer be shut down and that the SVE/AS System be operated with off-gas treatment limited to the activated carbon filter.

After reviewing this letter, Mr. Henry Cui (MADEP) requested that the contractor consider potentially impacted receptors and provided technical assistance in a document titled "Bureau of Waste Site Cleanup Policy #WSC-94-150". Atlantic Environmental Technologies (consultant to Mr. Gardner) provided written response to Mr. Robert Davis of the IRP office regarding the implementation of this policy. In this letter, A.E.T. provided calculations based on concentration of vapors from sampling conducted during operations, and followed the WSC-94-150 guidance on computing safe emission concentrations and minimum distances to potentially impacted receptors.

After a review of all data presented in this matter, USEPA and MADEP granted verbal approval to IRP to shut down the catalytic oxydizer on 12 June, 1997. Therefore, all soil gas vapors are now treated by the vapor phase activated carbon unit only. We will replenish this unit with fresh activated carbon when emission concentrations of total hydrocarbons (effluent from the carbon unit) exceed 5 ppm. This letter is provided to document these past activities and verbal agreements between our offices.

If you have any questions on this matter please call me at (508) 968-4670 ext. 4676.

Sincerely



EDWARD L. PESCE, P.E.
Environmental Engineer

Attachments:

1. AET Shut down of Cat/Ox Unit at FS-12.
2. Bureau of Waste Site Cleanup Policy #WSC-94-150.
3. Letters to MADEP and USEPA Requesting a Shut Down of the Cat/Ox Unit with cover letter to IRP.

cc:

Jim Snyder, AFCEE
Mike Minior, IRP
Dave Gardner, DGC, INC.
Bob Davis, IRP
Joe Hawk, ASI

MAILING ADDRESS
& BILLING OFFICE:
300 County Rd.
P.O. Box 599
Monument Beach, MA 02553
(508) 759-2155



OFFICE & SHOP:
11 Eel Pond Road
Monument Beach, MA 02553
(508) 759-2155

DAVE GARDNER, CONTRACTOR, INC.

27 May, 1997

Mr. Ed Pesce
Installation Restoration Program
Otis ANG Base, Mass.

Re; DAHA19-94-C-0026 air sparging/soil venting FS-12 site, MMR.

Dear Mr. Pesce,

Enclosed are copies of letters to the Mass. D.E.P. and the U.S. E.P.A. requesting a change in the equipment operation at FS-12.

The change involves the shut-down of the catalytic oxidizer and cooling system pump, and using the vapor phase carbon filter only for destruction of VOCs. The influent temperature is high enough that pre-heat is not required and, therefore, neither is the heat exchanger.

The cost of the vapor phase carbon change-outs will be borne by my Company.

Very truly yours,

A handwritten signature in black ink, appearing to read 'D. Gardner', with a long, sweeping horizontal line extending to the right.

David R. Gardner
President

encl.: Mass. D.E.P.
U.S. E.P.A.

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DAVE GARDNER, CONTRACTOR, INC.

27 May, 1997

Mr. Paul N. Marchesault, Remedial Project Manager
Federal Facilities Superfund Section
U. S. Environmental Protection Agency
John F. Kennedy Federal Building
Boston, Mass. 02203-0001

Re; DAHA19-94-C-0026 AIR SPARGING/SOIL VENTING FS-12 SITE, MASS.
MILITARY RESERVATION.

Dear Mr. Marchesault,

This Contractor, with the approval of Mr. Ed Pesce of the Installation Restoration Program at Otis, request a change in the equipment procedures for the final remediation of the FS-12 site.

The current system uses a catalytic oxidizer combined with a vapor phase carbon filter for the destruction of influent VOCs. The Remedial Action Work Plan, addendum two, phase two 'Project Closure', section 9.5 addresses the possibility of reconfiguring the APCU to use only the vapor phase carbon filter for COU removal. Carbon tube analysis of the influent has shown a decrease for the past four months below the 5 ppm level referred to (copies of results enclosed).

I request your approval to make this configuration change in the APCU system. Thank you for your assistance.

Very truly yours,

A handwritten signature in black ink, appearing to read 'D. Gardner', with a long, sweeping horizontal line extending to the right.

David R. Gardner
President

encl. 4 months test results

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DAVE GARDNER, CONTRACTOR, INC.

27 May, 1997

Mr. Leonard J. Pinaud, Acting Co-Chief
Federal Facilities Remediation
Mass. Department of Environmental Protection
20 Riverside Drive
Lakeville, Mass. 02347

Re; DAHA19-94-C-0026 AIR SPARGING/SOIL VENTING FS-12 SITE, MASS.
MILITARY RESERVATION.

Dear Mr. Pinaud,

This Contractor, with the approval of Mr. Ed Pesce of the Installation Restoration Program at Otis, request a change in the equipment procedures for the final remediation of the FS-12 site.

The current system uses a catalytic oxidizer combined with a vapor phase carbon filter for the destruction of influent VOCs. The Remedial Action Work Plan, addendum two, phase two 'Project Closure', section 9.5 addresses the possibility of reconfiguring the APCU to use only the vapor phase carbon filter for COU removal. Carbon tube analysis of the influent has shown a decrease for the past four months below the 5 ppm level referred to (copies of results enclosed).

I request your approval to make this configuration change in the APCU system. Thank you for your assistance.

Very truly yours,

A handwritten signature in black ink, appearing to read 'D. Gardner', written in a cursive style.

David R. Gardner
President

encl. 4 months test results



June 11, 1997

Mr. Robert Davis
Installation Restoration Program
Otis Air Force Base
Falmouth, Massachusetts

RE: Shutdown of Catalytic Oxidation Unit at FS-12

Dear Mr. Davis:

In accordance with Section 9.5 of the Closure Plan, if influent BTEX compounds are below five (5) ppm for two (2) consecutive months, the contractor may request to shutdown the catalytic oxidation unit and reconfigure the system to operate solely as a vapor-phase carbon unit. The purpose of this letter is to request, on behalf of Dave Gardener Contractor, Inc., permission to reconfigure the FS-12 remediation system and shut down the catalytic oxidation unit. The system will continue to operate with a vapor-phase carbon recovery unit prior to discharging the effluent air stream into the atmosphere.

In accordance with the Remedial Action Work Plan, Atlantic Environmental Technologies, Inc. (AET) has been conducting monthly monitoring of the influent and effluent air streams at FS-12. The samples were collected with carbon tubes for laboratory analysis of BTEX and EDB concentrations. According to the laboratory reports, the influent BTEX concentrations have been less than five (5) ppm for the last seven sampling events with an average BTEX concentration of 0.82 ppm. For BTEX concentrations below the detection limit, AET assumed a concentration equal to one-half of the detection limit.

In addition, the Massachusetts Department of Environmental Protection (MADEP) has developed technical guidance with respect to evaluating the need for off-gas controls at SVE systems. The guidance provides an equation, based upon emission rates at the system, for the minimum distance a Potentially Impacted Receptor may be located without requiring off-gas controls. The document, Bureau of Waste Site Cleanup Policy #WSC-94-150, defines a Potentially Impacted Receptor as:

- 1) residential properties, schools, daycare centers or elder-care facilities
- 2) parks, playgrounds and recreation areas
- 3) off-property commercial areas where continuing exposure to human receptors is likely
- 4) on-property areas where continuing, non-occupational exposure to a human receptor is likely (i.e., a former gasoline service station now being utilized as a restaurant.)



Potentially Impacted Receptors beyond the minimum distance will not, according to the MADEP guidance document, be impacted by system emissions.

AET calculated the minimum distance using influent BTEX concentrations during the past three (3) sampling events (refer to attachments). For concentrations below the laboratory detection limit, AET assumed a concentration of one-half the detection limit. Based upon our calculations, the minimum distance for a Potentially Impacted Receptor is approximately sixty nine (69) meters. The nearest Potentially Impacted Receptor, as defined by MADEP, is the Camp Good News property located approximately seven hundred thirty (730) meters from the system discharge point. Therefore, based on our calculations, the FS-12 SVE/AS system could operate at current influent concentrations without any off-gas controls.

With respect to safety within the sixty nine (69) meter distance, AET considered the NIOSH Time Weighted Average (TWA) and Short Term Exposure Limits (STEL) for the BTEX compounds compared with the average influent concentrations. The associated values are presented in the table below:

COMPARISON of NIOSH VALUES
and INFLUENT BTEX CONCENTRATIONS

Analyte	NIOSH (ppm)		Average Influent Conc. (ppm)
	TWA	STEL	
Benzene	0.1	1	0.059
Toluene	100	150	0.016
Ethyl Benzene	100	125	0.015
Total Xylenes	100	150	0.047

Based on the past three (3) sampling events, the average influent concentration of each of the BTEX compounds was well below the NIOSH standards. Therefore, assuming no off-gas treatment is conducted at the FS-12 site, workers at the site will be exposed to average BTEX compounds within acceptable limits.

However, the purpose of this letter is to request permission to shut down the catalytic oxidation unit currently used in conjunction with a carbon recovery unit for off-gas treatment. It is the contractors intention to continue to treat the off-gas air stream with the carbon recovery unit that will further increase the safety to nearby receptors and on-site personnel. It is our opinion that the catalytic oxidation unit can be decommissioned and the SVE/AS remediation system at FS-12 can be safely operated with off-gas treatment limited to carbon recovery.



If you have any questions regarding this issue, please contact us at your convenience.

Very truly yours,

ATLANTIC ENVIRONMENTAL TECHNOLOGIES, INC.

A handwritten signature in black ink, appearing to read "Timothy Condon", written in a cursive style.

Timothy Condon
Environmental Engineer

A handwritten signature in black ink, appearing to read "Toivo A. Lamminen, Jr.", written in a cursive style.

Toivo A. Lamminen, Jr., L.S.P.
Project Manger

Attachments: Calculation Sheets - Based on BWSC Policy #WSC-94-150

cc: David Gardner - Dave Gardner Contractors, Inc.

The purpose of this calculation is to evaluate the need to apply off-gas treatment to the SVE/AS system operating at FS-12. The methodology was developed by MADDEF and is based upon air emission rates and distance to Potentially Impacted Receptors. The methodology is presented in MADDEF's Policy # WSC-94-150.

Soil Vapor Extraction Systems

$$E = C_s(Q_s) \frac{2118}{2118}$$

E = air emission rate ($\mu\text{g/s}$)
 C_s = air (stack) conc ($\mu\text{g/m}^3$)
 Q_s = air (stack) flow rate (cfm)

For FS-12,

$$C_s = 516.67 \mu\text{g/m}^3 \text{ (refer to sheet 2)}$$

$$Q_s = 3,000 \text{ cfm (average flow rate of system)}$$

$$E = \frac{516.67(3,000)}{2118} = 731.83 \mu\text{g/s}$$

MADDEF provides the following equation in its methodology to calculate the minimum distance a Potentially Impacted Receptor may be without requiring off-gas controls

$$\text{Distance} = 805 (\log E) - 518 \text{ (meters)}$$

For the emission rate at FS-12, the minimum distance a Potentially Impacted Receptor may be without requiring off-gas controls is:

$$\text{Distance} = 805 (\log 731.83) - 518$$

$$\text{Distance} = 69.2 \text{ meters}$$

Calculation of average BTEX concentration in influent airstream during the past three sampling events.

5/14/97 0.534 $\mu\text{g}/\text{l}$

3/21/97 0.257 $\mu\text{g}/\text{l}$

2/24/97 0.756 $\mu\text{g}/\text{l}$

1.547 $\mu\text{g}/\text{l}$

Average conc. = 0.516 $\mu\text{g}/\text{l}$
= 516.67 $\mu\text{g}/1000 \text{ l}$

$\Rightarrow (1000 \text{ l} = 1 \text{ m}^3)$

NOTE: For concentrations less than detectable limit, AET assumed a concentration equal to one half of the ~~det~~ detectable limit

OFF-GAS TREATMENT OF POINT-SOURCE REMEDIAL AIR EMISSIONS

Policy #WSC-94-150

This Policy concerns air emissions that occur as a result of air stripping of contaminated groundwater, extraction of soil gases, or any other remedial activity conducted pursuant to MGL Chapter 21E that creates a point-source discharge of contaminants to air. The intent of this Policy is to articulate when treatment of point-source remedial air emissions may be necessary to eliminate significant risks to human health, safety, public welfare, or the environment.

5/25/94
Date

James C. Colman
James C. Colman
Assistant Commissioner
Bureau of Waste Site Cleanup

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Dichloromethane	5	15
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Gasoline	8	18
Methyl Ethyl Ketone	6	16
Methyl-tertiary butyl ether	7	17
Naphthalene	5	15
Phenol	5	15
Tetrachloroethylene	4	14
1,1,1-Trichloroethane	7	17
Trichloroethylene	6	16
Toluene	5	15
Vinyl Chloride	4	14
Xylenes (total)	5	15

Background and Purpose

Remedial actions at sites contaminated by a release of oil and/or hazardous materials frequently involve the collection and treatment of groundwater and/or soil gases. Common treatment technologies often result in the emission of contaminated vapors to the ambient air. Emissions of this nature generally result from the operation of "air strippers" or soil vapor extraction (SVE) systems, designed to volatilize or "off-gas" contaminants from soil and/or groundwater to the atmosphere.

The purpose of this policy is to (1) describe the regulatory jurisdictions and procedures that govern emissions of this nature, (2) delineate and explain the required performance standards applicable to remedial emissions, (3) articulate details of a Best Response Action Management Approach (BRAMA), and (4) provide a simplified methodology for determining when off-gas controls should be considered.

The information contained in this document is intended solely for guidance. This document does not create any substantive or procedural rights, and is not enforceable by any party in any administrative proceeding with the Commonwealth. The regulations related to remedial air emissions contain both specific and general requirements. In addition to summarizing specific requirements, this document also provides guidance on what measures the Department considers acceptable for meeting the general requirements set forth in the regulations. Parties using this guidance should be aware that there may be acceptable alternatives to this guidance for achieving compliance with such general regulatory requirements.

Additional copies of this policy may be obtained by calling the DEF InfoLine at (617) 338-2255 or 1-800-462-0444.

Applicability

This policy applies to remedial actions being conducted at any disposal site as defined and regulated by the Massachusetts Department of Environmental Protection (DEP)/Bureau of Waste Site Cleanup (BWSC) under MGL c.21E and 310 CMR 40.0000, the "Massachusetts Contingency Plan", including disposal sites with waivers.

The guidance contained in this policy applies to any point-source remedial air emissions, such as, air discharges from packed-tower or diffused aeration air strippers, bioreactors, and SVE systems, except as described below.

This policy is neither designed nor intended to apply to the following:

- (1) Well-head treatment systems at public water supply wells that are operated in conformance with the provisions of DEP Policy # DWS-88-01 and/or in conformance with requirements specified by the DEP Division of Water Supply.
- (2) Sub-Slab Depressurization Systems installed at residential dwellings, schools, or commercial buildings to prevent the migration of subsurface vapors into living/working spaces, provided the total air emission rate of all volatile contaminants is less than 100

pounds/year.

- (3) Point-source remedial air emissions temporarily authorized by DEP to prevent or abate an imminent hazard to health, safety, public welfare, or the environment, as described in 310 CMR 40.0040(4). In such cases, treatment devices, when necessary, must be installed as soon as possible.

However, DEP reserves the right to require off-gas controls on the above discharges should such emissions (1) presently or potentially exceed significant risk level concentrations or (2) create odorous or adverse health, safety, or environmental conditions downwind of the discharges.

Regulatory Jurisdictions

While point-source remedial air emissions are regulated primarily by DEP/BWSC under MGL c.21E and 310 CMR 40.0000, remedial air emissions **that will exceed 1 ton/year** (with or without off-gas treatment/controls) are also subject to the regulatory provisions specified by DEP/Bureau of Waste Prevention (BWP) under MGL c.111, section 142 A-K and 310 CMR 7.00, the "Massachusetts Air Pollution Control Regulations." Under these provisions, two options exist to satisfy BWP requirements:

- (1) the proponent of the remediation may file an appropriate permit/plan application, as specified in 310 CMR 7.02; or
- (2) the proponent of the remediation may, under the "permit by rule" provisions of 310 CMR 7.03, elect to apply off-gas control treatment (if not already required by BWSC requirements under 310 CMR 40.0040) for groundwater or soil venting systems that ensures 95% removal of volatile emissions, and implement specified monitoring and documentation procedures.

At most disposal sites remediated under MGL c 21E, remedial air emissions are less than 1 ton/year (even without treatment), and in most cases, will not require an air discharge permit from BWP. Regardless of emission levels, however, BWP has the authority to require a plan application or permit if such emissions create or contribute to a condition of air pollution.

Performance Standards for Determining When to Apply Off-Gas Controls

Background

Under the provisions of 310 CMR 40.0000, DEP/BWSC has established requirements and procedures for conducting remedial actions at contaminated sites in a manner which is protective of human health, safety, public welfare, and the environment. Specifically, 310 CMR 40.0040 ("Remedial Air Emissions") stipulates that point-source air emissions from remedial systems must be treated by control devices prior to their discharge to ambient air, unless the person undertaking the response action submits a Licensed Site Professional (LSP) Opinion to DEP prior to commencement of the remedial action stating that such emissions, if not treated, would be at or below a level of No Significant Risk to health, safety, public welfare, and the environment.

Once installed, off-gas controls must be maintained until such time that an LSP Opinion is submitted stating that such off-gas controls are no longer needed.

No Significant Risk

In order to achieve compliance with 310 CMR 40.0040, emissions from remedial systems must be at or below a level of No Significant Risk to health, safety, public welfare, and the environment. "No Significant Risk" exists when all of the following conditions are met:

Human Health

A condition of No Significant Risk to human health shall exist if the risk of harm to persons exposed to remedial air emissions meet the risk management criteria specified in 310 CMR 40.0902(2):

- using a cumulative risk approach, the risk associated with the remedial air emissions must be equal to or less than the Cumulative Cancer Risk Limit (an Excess Lifetime Cancer Risk of one-in-one hundred thousand), and the Cumulative Noncancer Risk Limit (a Hazard Index of 1.0); or
- using a chemical-specific approach, the receptor concentration resulting from each oil or hazardous material emitted must be equal to or lower than either the concentrations of that chemical which are associated with an Excess Lifetime Cancer Risk of one-in-one million and a Hazard Index of 0.2, or equivalent concentrations identified by DEP to meet the objectives of the chemical specific risk approach.

In accordance with the provisions of 310 CMR 40.0902(3), concentrations of oil and hazardous materials in ambient air at background concentrations shall be assumed to constitute a condition of No Significant Risk to human health.

Safety

In accordance with the provisions of 310 CMR 40.0960, a condition of No Significant Risk to human safety shall exist if:

- remedial air emissions do not result in the generation and/or accumulation of explosive vapors; and
- access to remedial treatment systems are restricted as needed to prevent physical harm or bodily injury.

Public Welfare

In accordance with the provisions of 310 CMR 40.0900 and 40.0994(2), a condition of No Significant Risk to public welfare exists if:

- remedial air emissions do not result in nuisance odor conditions at downwind human

receptors. For the purpose of predicting the occurrence of such odor conditions, the 50th percentile odor recognition concentration should be utilized.

Environment

In accordance with the provisions of 310 CMR 40.0995, a condition of no significant risk to the environment exists if:

- remedial air emissions and/or fallout from remedial air emissions do not result in a deleterious impact to critical habitat, endangered species, or other sensitive ecological receptors.

Demonstrating No Significant Risk

Prior to the commencement of remedial actions where off-gas controls WILL NOT be applied to systems emitting contaminated vapors, an LSP Opinion must be submitted stating that such emissions will not exceed a level of No Significant Risk at Potentially Impacted Receptors. This Opinion shall be based upon an analysis of the following:

- (1) threshold (non-carcinogenic) and non-threshold (carcinogenic) health risks resulting from each oil and hazardous material emitted to the atmosphere, to evaluate risks to human health;
- (2) potential odor conditions resulting from such emissions, to evaluate risks to public welfare; and
- (3) direct impacts of emissions on ecological parameters to evaluate risks to the environment.

Please note that potential risks to human safety should also be considered when undertaking any remedial action at a disposal site (See Section 4.0 [B]).

To facilitate the demonstration of No Significant Risk, mathematical models may be used to predict increased ambient air concentrations at Potentially Impacted Receptors. The following guidance is provided on the appropriate application of models:

Mathematical models typically calculate (increased) maximum hourly concentration values at a specified down-wind receptor. These computed maximum hourly concentration should be:

- (1) multiplied by 0.40, to obtain an estimate of the average (increased) daily receptor concentration value, in order to evaluate threshold health risks;
- (2) multiplied by 0.08, to obtain an estimate of the average (increased) yearly receptor concentration, in order to evaluate non-threshold health risks; and
- (3) remain unadjusted (maximum hourly concentrations), to evaluate potential receptor odor concerns.

The use of the above multiplying factors are consistent with standard statistical averaging practices, as used and recommended by DEP and the U.S. Environmental Protection Agency (EPA).¹

To evaluate non-threshold health risks, DEP Allowable Ambient Limits (AALs) for Air may be used. If used in this manner, individual AALs may be adjusted to reflect the time period of proposed remedial emissions. To evaluate threshold health risks, DEP Threshold Effects Exposure Limits (TELs) may be used. The use of a 50th percentile odor recognition concentration should be used to evaluate the potential for odor impacts at Potentially Impacted Receptors.

For chemicals with background concentrations in ambient air exceeding a condition of No Significant Risk or an odor threshold, the required evaluation of potential health and odor concerns should be made on the basis of increased ambient concentration values resulting from the proposed remedial emission. For the purpose this policy, background concentrations of individual or collective VOCs should be determined by site-specific air sampling and analysis, or by citation of appropriate values from scientific literature.

Definition of and Distance to "Potentially Impacted Receptors"

In order to characterize the risk posed by oil and/or hazardous materials, human and environmental receptors must be identified in accordance with 310 CMR 40.0920. For the purposes of this policy, human receptors or "Potentially Impacted Receptors" include:

- (1) residential properties, schools, daycare centers, or elder-care facilities;
- (2) parks, playgrounds, and recreation areas;
- (3) off-property commercial areas where continuing exposure to a human receptor is likely; or
- (4) on-property areas where continuing non-occupational, exposure to a human receptor is likely (i.e. a former gasoline service station now being utilized as a restaurant).

In applying the recommended "Best Response Action Management Approach" (Section 6 of this policy) and the "Simplified Remedial Emission Evaluation Methodology" (Section 7), distances should be measured from the base of emission stack(s) to the nearest "Potentially Impacted Receptor" as described below:

- (1) the property boundary of the nearest residential dwelling;
- (2) the property boundary of the nearest school, daycare center, elder-care facilities, park, playground, and recreation area; or

¹ "Screening Procedures for Estimating the Air Quality Impact of Stationary Sources, Revised" (EPA-92-019), October 1992, provides a more detailed discussion of multiplying factors.

- (3) any on or off-property point where continuing exposure to a potentially impacted receptor is likely.

) Performance Standards for the Operation and Monitoring of Off-Gas Control Systems

Except where an LSP Opinion is submitted as specified by 310 CMR 40.0040(6) stating that achievement of a 95% level of emission reduction is not feasible or necessary, or where treatment standards are specified in writing by DEP based upon its review of proposed or ongoing response actions, off-gas control systems (e.g., activated carbon, incineration, catalytic or thermal oxidation, or biotreatment units) must be designed, constructed, and operated in a manner that:

- (1) as specified in 310 CMR 40.0040(5), ensures the continuous reduction of at least 95% of the emitted oil and hazardous material, on a weight basis, or reduction to background level, whichever concentration is higher;
- (2) does not expose down-wind receptors to concentrations exceeding a level of No Significant Risk; and
- (3) does not expose down-wind receptors to nuisance odor conditions.

The following are considered by DEP to be the minimum monitoring procedures for off-gas control systems necessary to ensure compliance with the 95% VOCs reduction performance standard. Proponents should continuously evaluate the need to expand on these minimum requirements during the operation of the treatment system.

- (1) Influent and effluent vapor samples should be obtained from the off-gas control system 1, 7, 14 and 28 days after system start-up, and monthly thereafter. Vapor samples should be analyzed using a portable GC, or they may be screened for total VOCs (vol/vol) using a photoionization detector (PID) or flame ionization detector (FID).
- (2) All VOC vapor samples should be obtained from "in-line" sampling ports in the vapor treatment system piping.
- (3) Documentation should be maintained detailing the daily instrument calibration procedure if a PID or FID is used; or instrument quality control results along with the influent and effluent analytical data if a portable GC is used.

) Best Response Action Management Approach

To meet the Best Response Action Management Approach (BRAMA) standard (310 CMR 40.0191), remedial action alternatives must be designed and implemented in a manner which is protective of health, safety, public welfare, and the environment. In evaluating whether off-gas controls are necessary to meet a condition of No Significant Risk, there are certain conditions which cannot be adequately addressed via air dispersion modeling. Moreover, unless continuous emission/ambient air monitoring is conducted, all site-specific remedial emission monitoring programs are subject to significant spatial and temporal data limitations.

Because of these concerns, the DEP considers that a Best Response Action Management Approach for remedial air emissions must take into account the following site and operational factors which could lead to significant emission fluctuations and receptor impacts in order to be protective of health, safety, public welfare, and the environment:

(1) Gasoline Releases

Gasoline releases represent a unique contamination profile due to the large and highly variable number of volatile organic compounds (VOCs) present, and cannot be adequately characterized by commonly available analytical and data evaluation techniques. Of particular concern are the potential public welfare problems that may result from the discharge of odorous compounds such as alkenes or biological degradation products. These factors must be considered prior to any decision to allow the untreated emissions of such contaminants.

(2) Non-Aqueous Phase Liquids (NAPL)

Release conditions where non-aqueous phase liquids, such as free-phase gasoline, are present represent a unique set of concerns. System failures could result in free-phase liquids entering air emission stacks. Globule/colloidal non-aqueous phase liquid entrainment into aqueous flow systems or volatilization into SVE systems, could result in transient, but potentially significant fluctuations in emission levels. To address these concerns, at sites where the point of groundwater recovery or SVE is within 10 meters of a location where measurable NAPL exists, off-gas controls should be applied to protect against the impact of such potential system failures on ambient air quality. Such a recommendation would not apply to bioventing systems at sites where non-volatile NAPL is present.

(3) Soil Vapor Extraction Systems

The recovery rate/air emission rate from SVE systems are unlike those of groundwater air stripping systems. In a typical SVE application, initial operation will produce a high air emission rate, followed by sharply reduced levels tailing off to a asymptotic steady-state condition. In order to effectively capture this initial contaminant mass and guard against transient discharge anomalies that could occur as a result of changing and dynamic vadose-zone conditions, all SVE systems should be initially fitted with off-gas control devices for the first 1500 hours of operation. Following this initial period, off-gas control devices should only be removed if none of the other application conditions articulated in Section 4.0 exist.

(4) Modeling Limitations

Because of limitations inherent in most mathematical models, off-gas control devices should generally be applied on any remedial system where the discharge stack height (point of emission) is less than 4.5 meters above ground level, or where the distance to the nearest Potentially Impacted Receptor is less than 20 meters from any emission stack.

) Simplified Remedial Emission Evaluation Methodology

A simplified methodology has been developed by DEP for evaluating the need to apply off-gas controls on remedial air emissions, based upon the air emission rate and distance to Potentially Impacted Receptors. Specifically, a series of emission-distance graphs have been developed to evaluate risks to human health and public welfare, based upon air dispersion modeling. The use of this methodology is optional.²

: Modeling Assumptions/Results

The EPA "Screen" Model (EPA-450/4-88-010) was used to help predict potential ambient air concentration levels of 20 targeted contaminants at varying distances from a point-source air discharge. Modeling inputs were designed to represent reasonably conservative, although not worst-case, site conditions and remedial system operational parameters. Modeling outputs were compared to designated "acceptable" increased ambient receptor concentrations. For the universe of targeted compounds, "acceptable" increased ambient receptor concentrations were defined as the lowest of the following three values: (1) the Allowable Ambient Limit value multiplied by 75/5 (to account for 5 year exposure-duration carcinogenic effects), (2) the Threshold Effect Level, and (3) the odor threshold.

Model output data for air plume "wake" areas were used to formulate a series of emission-rate vs. distance-to-receptor graphs. The 20 targeted contaminants were grouped into 4 categories, based upon commonality of "acceptable" receptor concentration values.

Modeling results indicate the possibility of deleterious air plume "cavity effects" within 20 meters of the emission point. Accordingly, off-gas controls should always be applied for all emission stacks located less than 20 meters from a "potentially impacted receptor."

: Calculating Air Emission Rate

For Air Strippers, the remedial air emission rate should be calculated as follows:

- (1) Unless a pilot study has been undertaken to determine steady-state influent groundwater concentrations, the highest aqueous concentration value for each contaminant from within the projected recovery area should be the designated influent concentration level.
- (2) The air emission rate ($\mu\text{g/s}$) may be directly obtained from Figure 1 using the influent concentration(s) determined in (1) above and the proposed process flow rate through the system. Air emission rates corresponding to influent concentrations outside the range provided in Figure 1, should be indirectly calculated for each influent contaminant assuming 100% mass-transfer from the aqueous phase, according to the relationship:

$$E = [C_w * Q_w] / 15.84$$

² The "Point-Source Air Emissions from 21E Remedial Systems" discussion document, dated June 26, 1992, provides a more detailed description of the air dispersion modelling.

where:

E = air emission rate, $\mu\text{g/s}$
 C_w = aqueous concentration, $\mu\text{g/l}$
 Q_w = influent aqueous flow rate, gal/min

For Soil Vapor Extraction (SVE) Systems, the remedial air emission rate should be calculated as follows:

- (1) Stack concentrations should be measured directly from a sampling port in the stack by obtaining a vapor sample for analysis on a portable or laboratory gas chromatograph (GC).
- (2) The air emission rate ($\mu\text{g/s}$) may be directly obtained from Figure 2 or 3 using the effluent vapor concentration(s) determined in (1) above and the proposed process flow rate through the system. Air emission rates corresponding to effluent vapor concentrations outside the range provided in Figure 2 or 3, should be determined for each contaminant, according to the following relationship:

$$E = [C_s * Q_s] / 2118$$

where:

E = air emission rate, $\mu\text{g/s}$
 C_s = air (stack) concentration, $\mu\text{g/m}^3$
 Q_s = air (stack) discharge rate, CFM

Air emission rate, in $\mu\text{g/s}$, from other remedial systems should be determined by the most appropriate method(s).

Using Emission-Distance Graphs

Five emission-distance graphs are provided.

- (1) The emission-distance graphs (Figures 4 through 8) should, in most cases, address potential impacts to human health and public welfare; project proponents must still satisfy the safety and environmental performance standards specified in Section 4.

However, due to the high degree of uncertainty in predicting odorous conditions at downwind receptors, DEP may require off-gas treatment at locations where odors are present, regardless of the need for such treatment as determined using the simplified graphical approach.

- (2) For each **individual** site contaminant, select the appropriate graph and plot the calculated air emission rate ("x" axis) against the distance to nearest "potentially impacted receptor" ("y" axis). If **any** coordinate point for **any** individual contaminant is below the designated line, then off-gas controls should be applied.

- (3) Figure 8 should be used for all sites where a gasoline release has occurred to address benzene, toluene, ethylbenzene, and total xylenes (BTEX), and methyl-tertiary butyl ether (MTBE) contaminant levels. In Figure 8, the collective air emission rate for BTEX and MTBE is plotted against the distance to the nearest "potentially impacted receptor". If this coordinate point is below the designated line, then off-gas controls should be applied. (Other non-gasoline related contaminants, if present, must also be addressed by Figures 4 through 7).
- (4) Figure 8 SHOULD NOT be used for sites where individual concentrations of benzene, toluene, ethylbenzene, xylenes, or MTBE are present, and their presence is NOT attributable to a release of gasoline. In these cases, the emission conditions should be addressed using Figures 4 through 7.

0 Licensed Site Professional Opinions

All LSP Opinions, as described in this policy and 310 CMR 40.0040, must be accompanied by the appropriate level of documentation to support the particular Opinion. Specifically:

- (1) an LSP Opinion submitted to DEP prior to the commencement of the remedial action stating that untreated emissions will present No Significant Risk, as described in 310 CMR 40.0040(3), must be supported by information and reasoning which addresses all of the criteria outlined in 40.0040(3)(a) through (e). As this provision requires the LSP to consider "all relevant policies issued by the Department", i.e., this Policy, the LSP Opinion should address why it is not necessary to apply off-gas controls to meet the conditions outlined in Section 4.0 of this Policy in order to achieve the No Significant Risk standard;
- (2) an LSP Opinion submitted stating that off-gas controls are no longer necessary in order to achieve the No Significant Risk standard, based on the absence of all of the conditions outlined in Section 4.0 of this policy must be supported by an adequate description of why those conditions no longer apply; and
- (3) an LSP Opinion submitted stating that 95% reduction in level of emissions is not feasible or necessary, as described in 310 CMR 40.0040(6), must be supported by the information and reasoning used to reach this conclusion.

Although the LSP Opinions listed above are not required for response actions conducted at sites with approved waivers, an evaluation of the need for controls is necessary and documentation of such an evaluation should be submitted to DEP.

Figure 1
Air Stripper Emission Rate vs.
Influent Groundwater Concentration

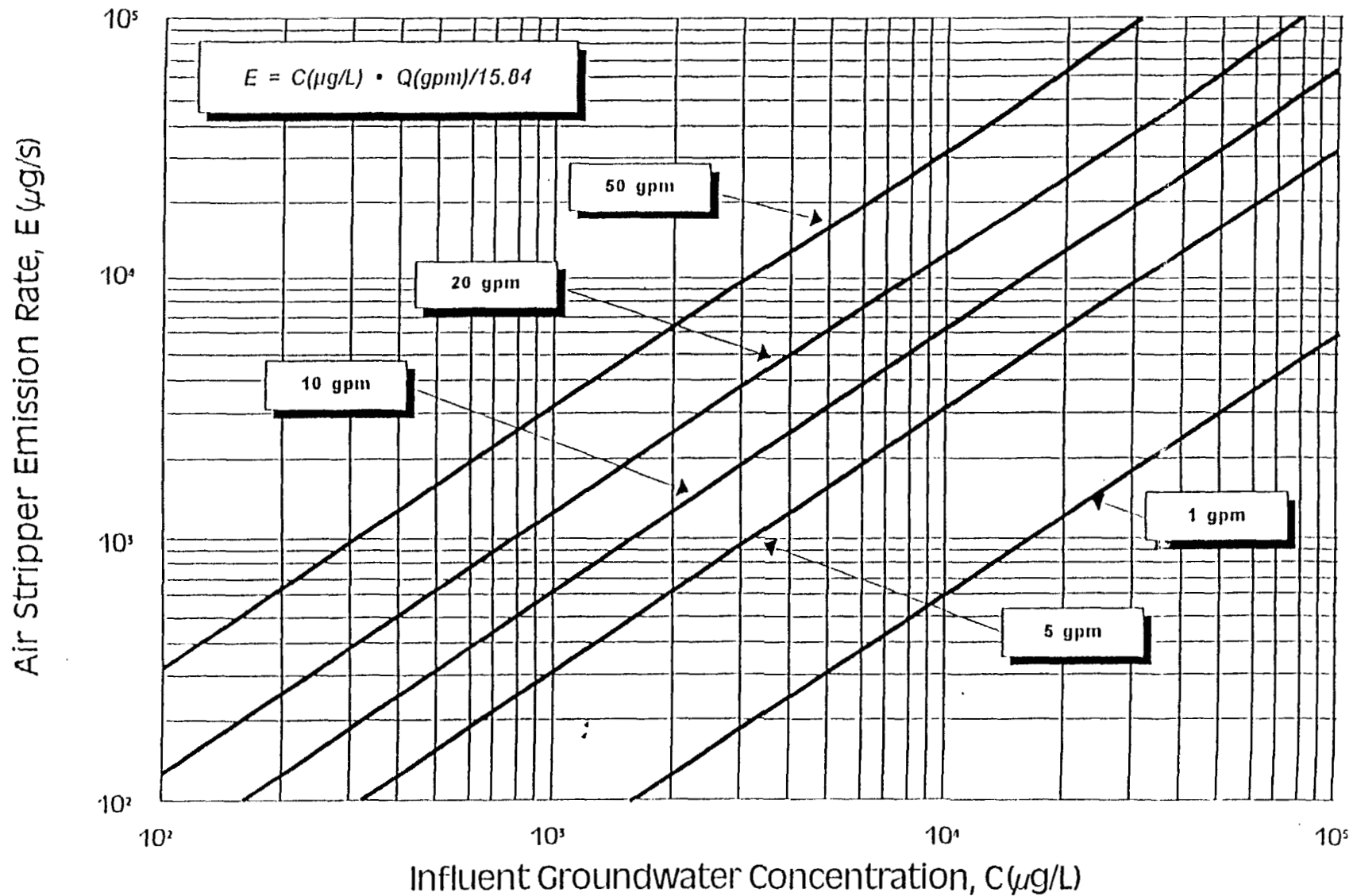


Figure 2
SVE Emission Rate vs. Vapor Concentration

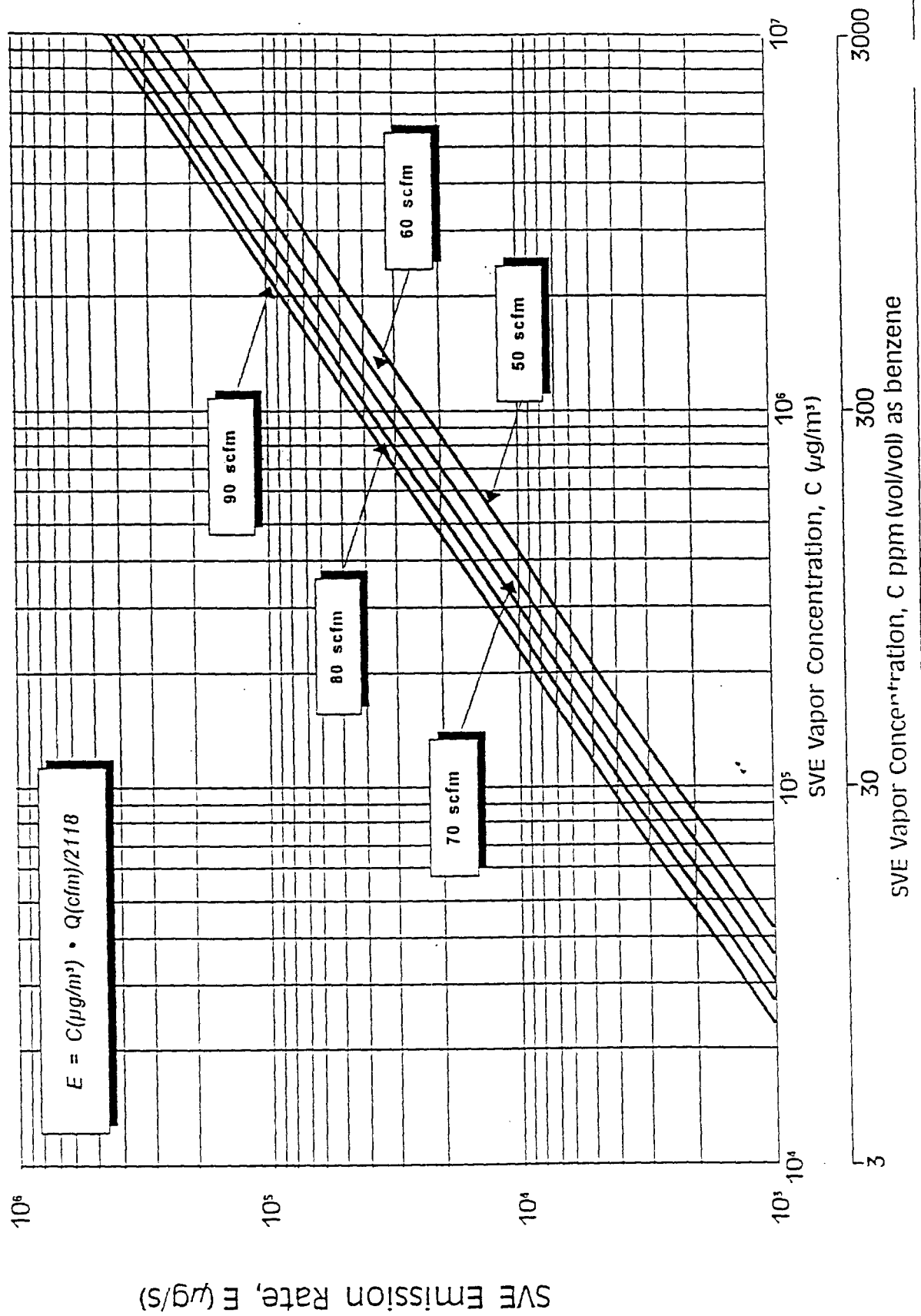


Figure 3
SVE Emission Rate vs. Vapor Concentration

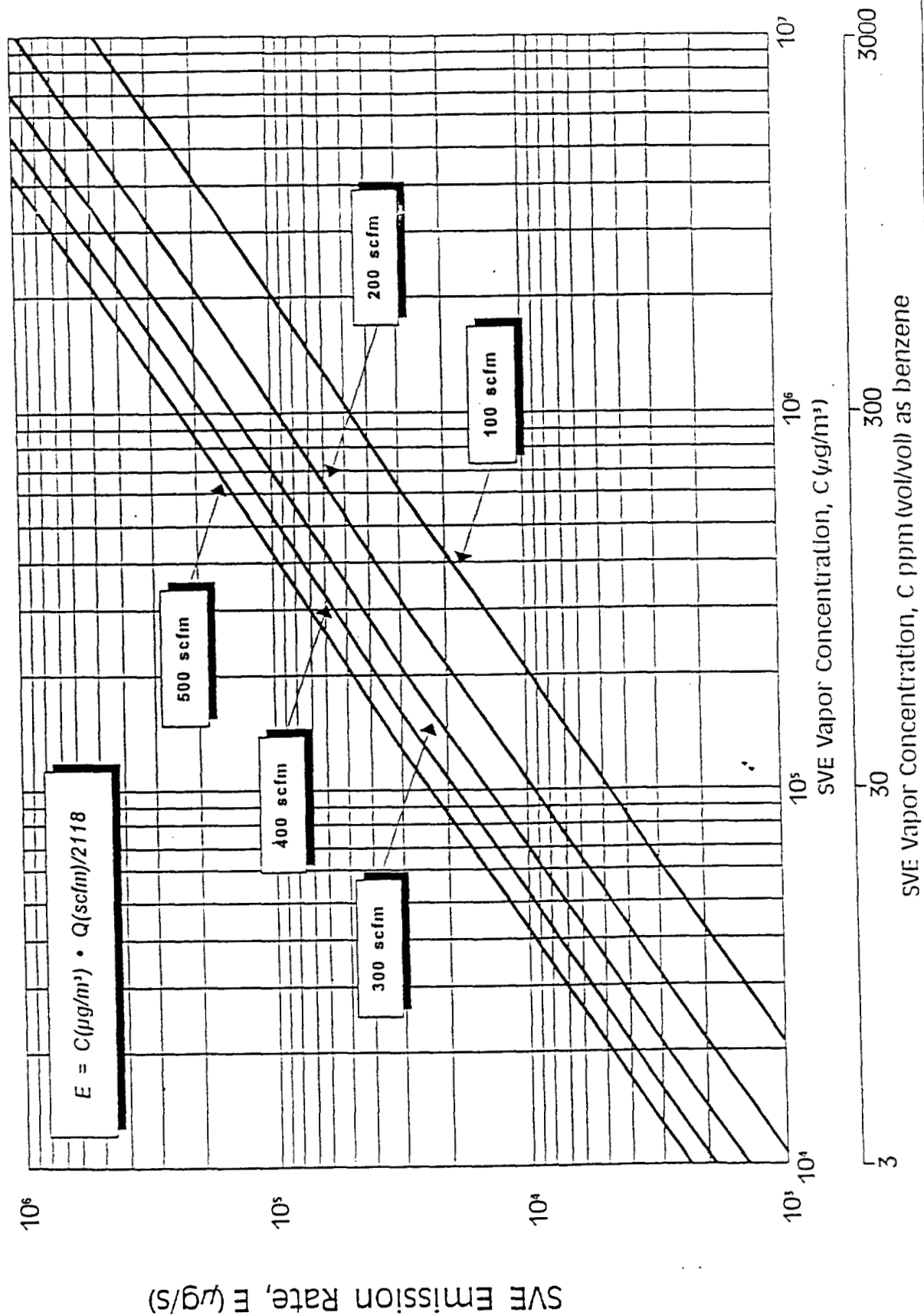


Figure 4
Emission Rate vs. Distance: Group 1

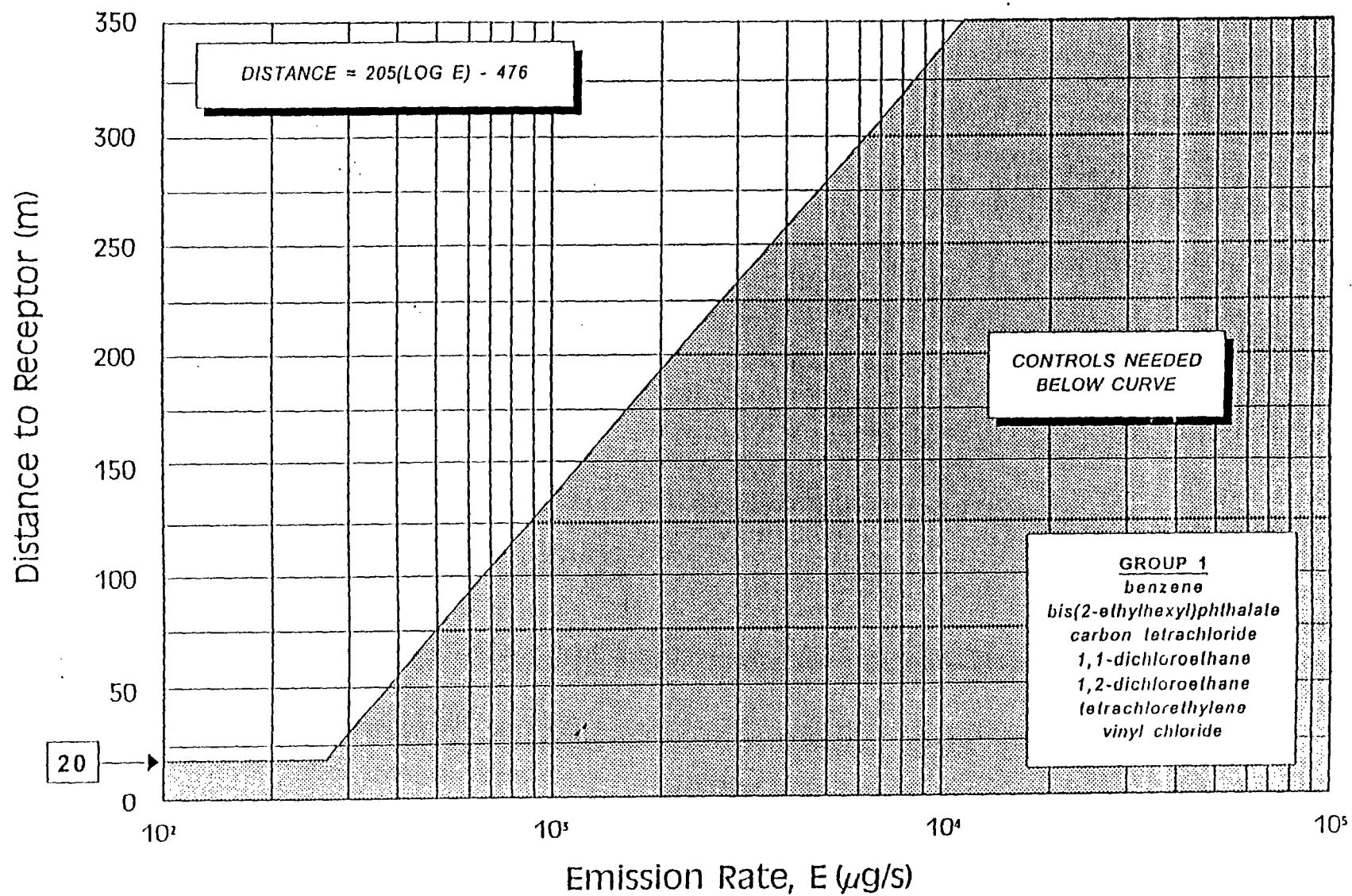


Figure 5
Emission Rate vs. Distance: Group 2

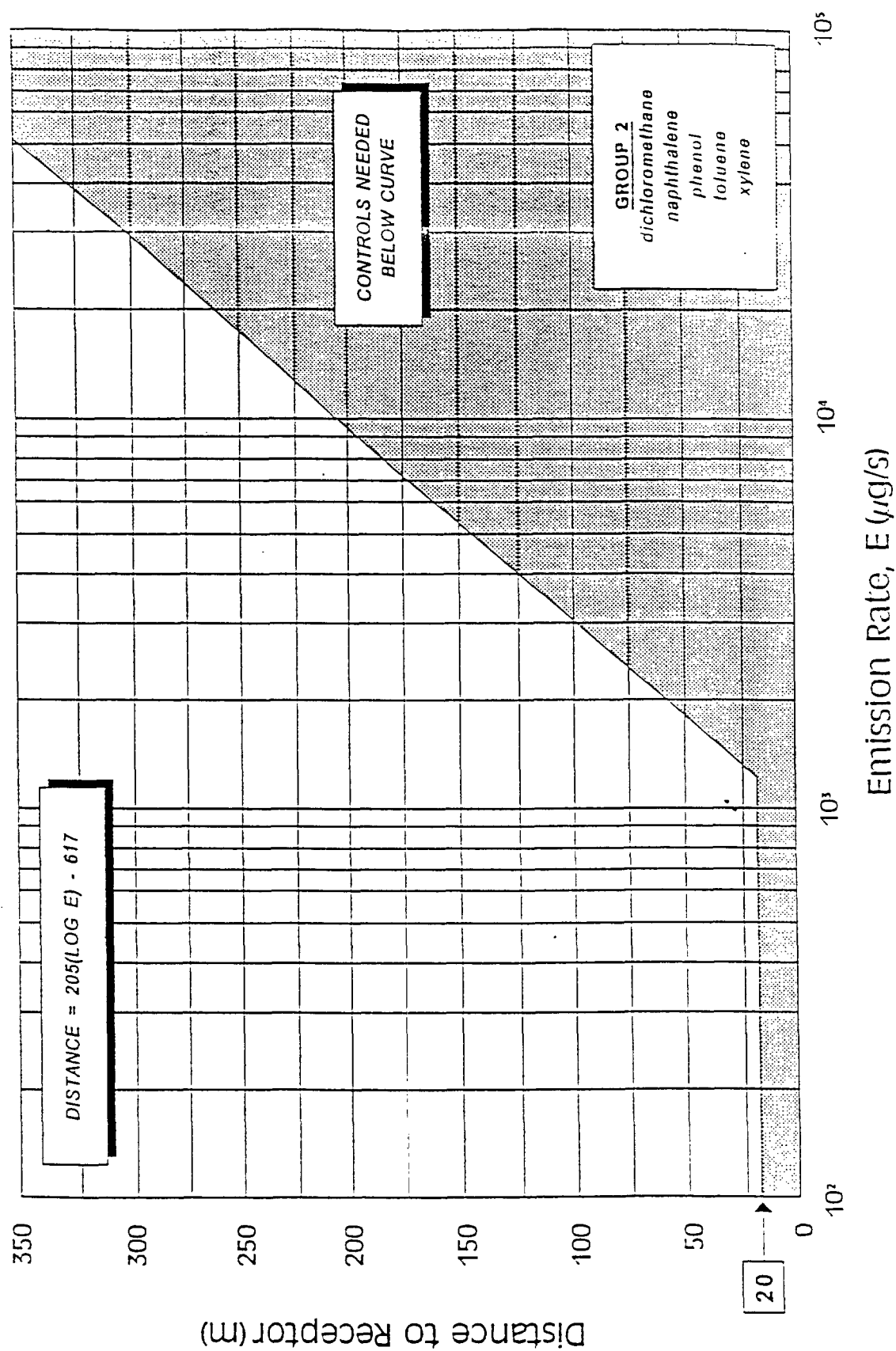


Figure 6
Emission Rate vs. Distance: Group 3

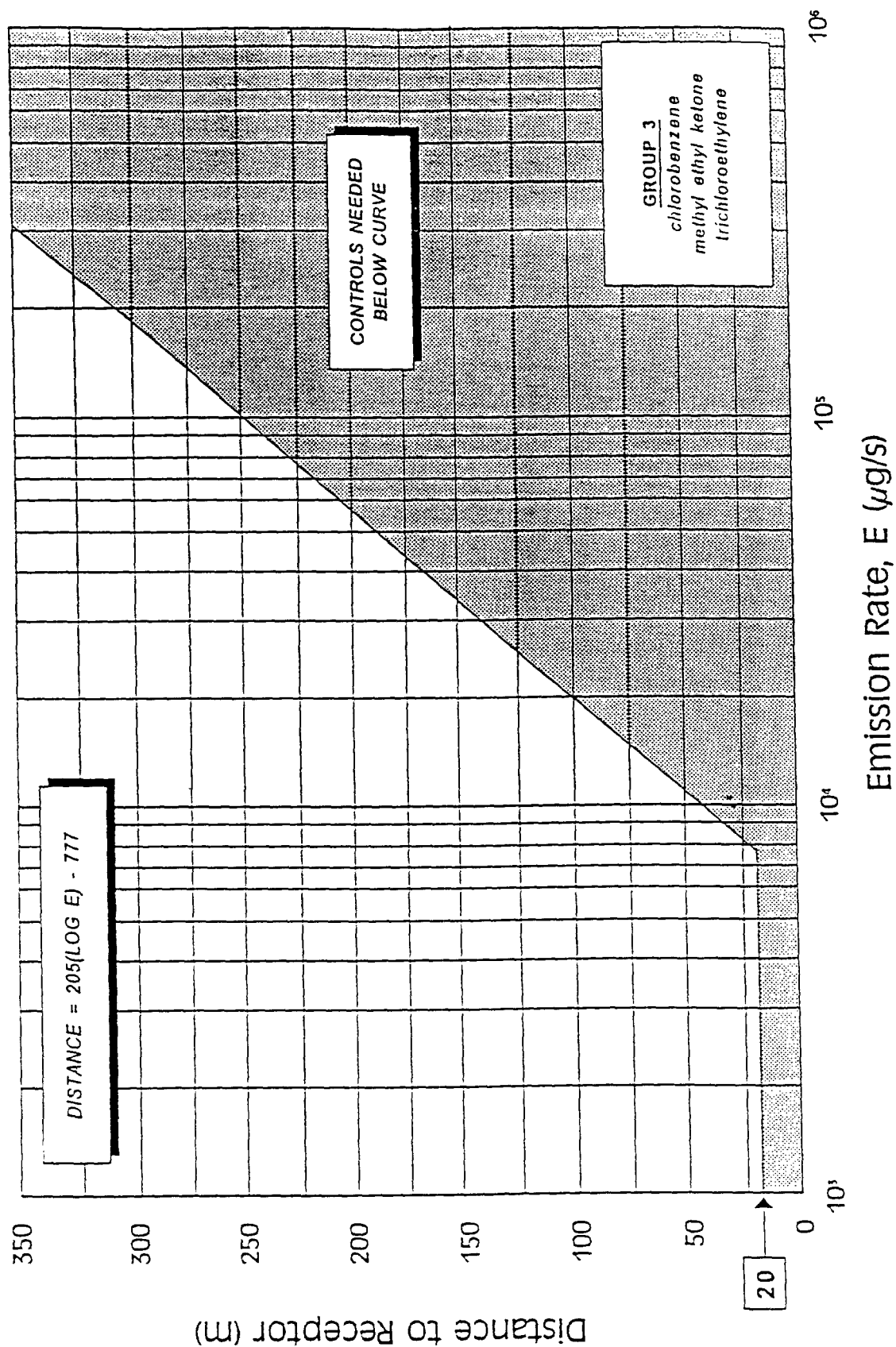


Figure 7
Emission Rate vs. Distance: Group 4

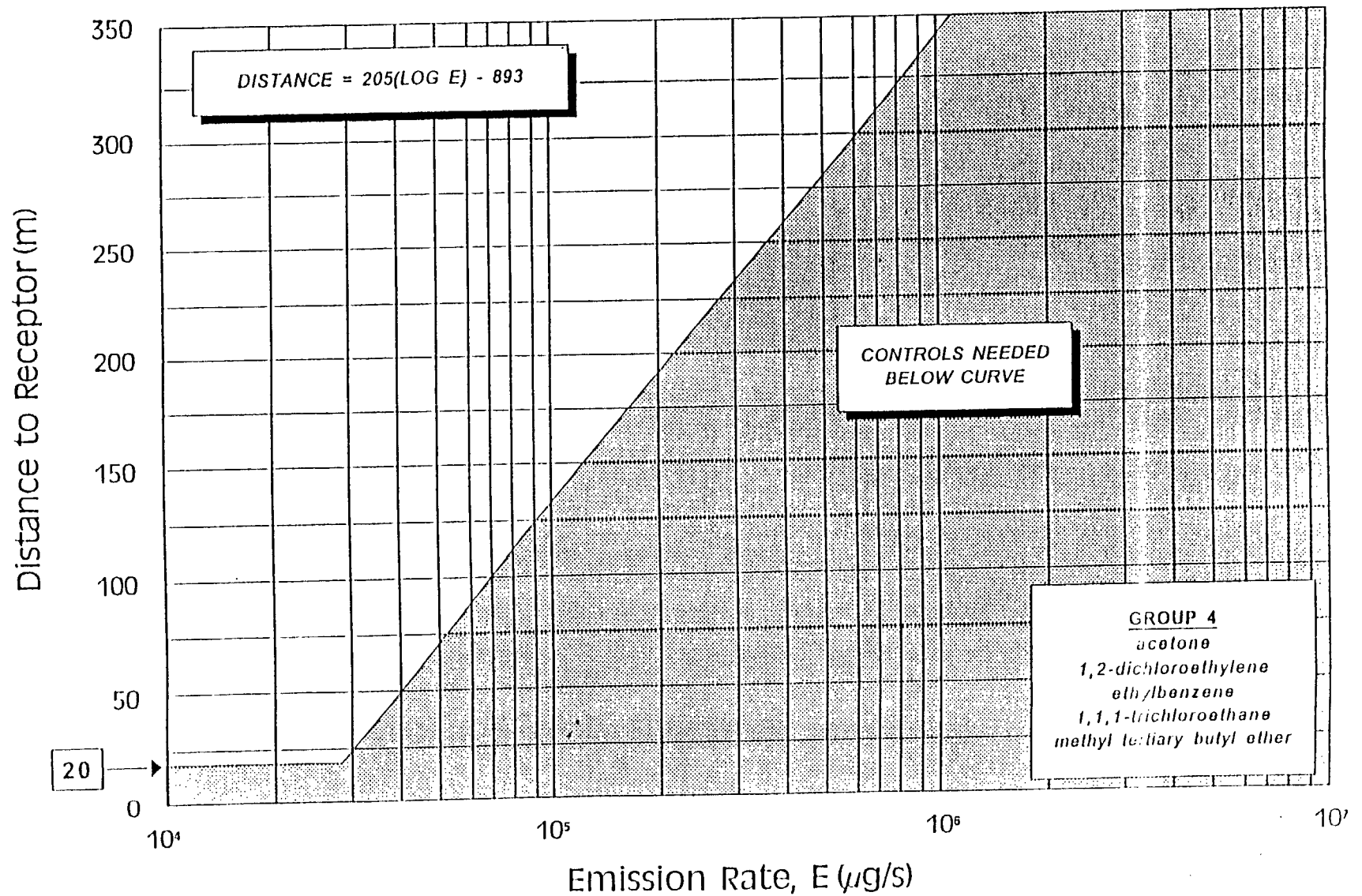
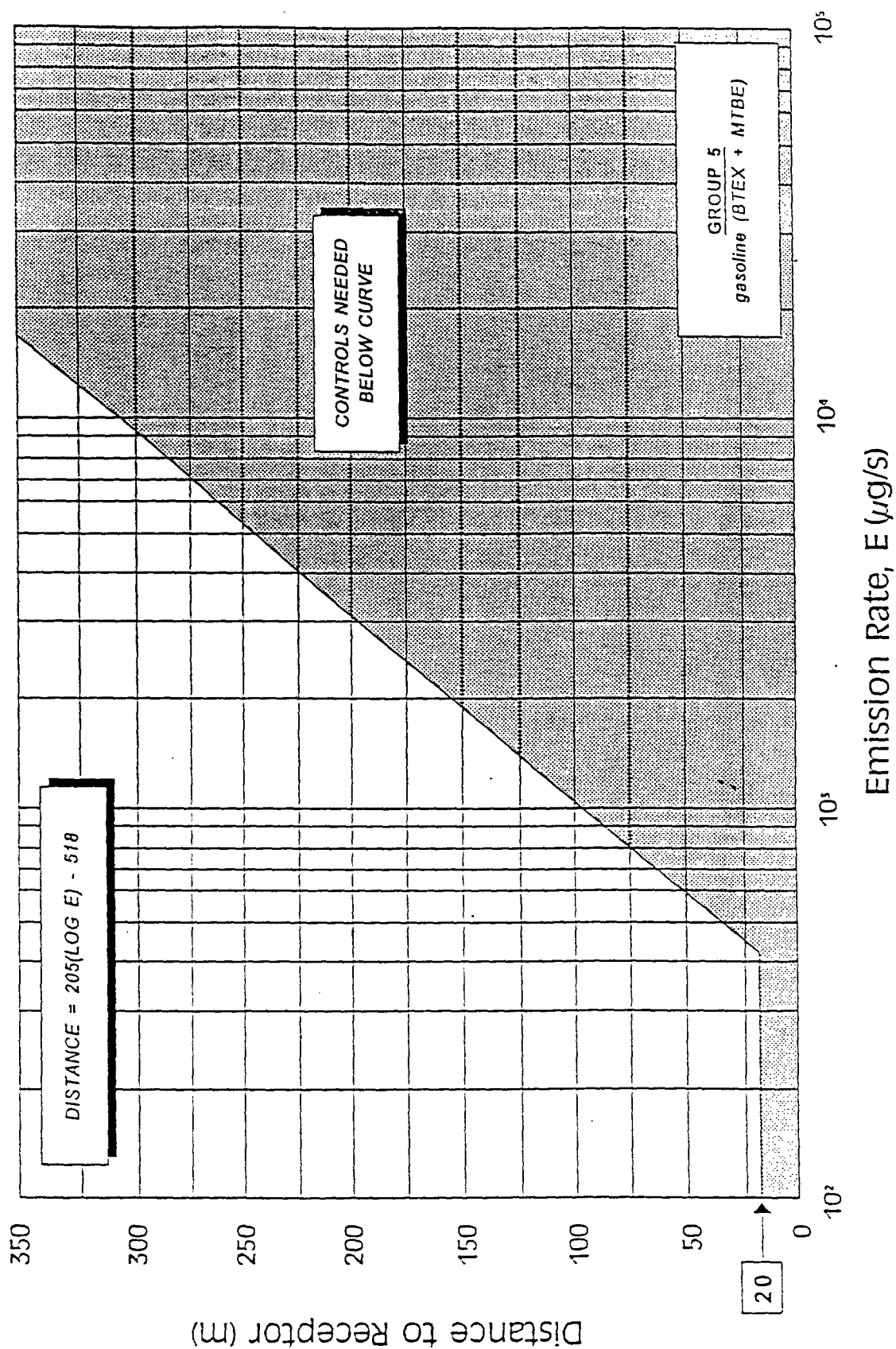


Figure 8
Emission Rate vs. Distance: Group 5





UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION I
JOHN F. KENNEDY FEDERAL BUILDING
BOSTON, MASSACHUSETTS 02203-0001

July 16, 1997

James Snyder, Project Manager
HQ AFCEE/MMR
322 East Inner Road
Box 41
Otis ANG Base, MA 02542

Re: FS-12 Source Catalytic Oxidation Unit Shut Down

Dear Mr. Snyder:

I am in receipt of your "memorandum for the record" letter dated July 2, 1997 relative to the shut down of the catalytic oxidizer at the FS-12 Air Sparging and Soil Venting System. Upon review, this office concurs that the off-gas treatment be limited to the activated carbon filter based on the levels that have been detected, which is consistent with the Remedial Action Work Plan. If the levels should increase substantially again over time, then the possible use of the catalytic oxidizer must be reconsidered.

If you have any questions, please do not hesitate to call me at (617) 573-5793.

Sincerely,

Paul N. Marchessault, Remedial Project Manager
Federal Facilities Superfund Section

cc: Michael Minior, NGB
Ed Pesce, NGB
Joe Hawk, ASI
Toivo Lamminen, Atlantic Environmental Technologies
Dave Gardner
Leonard Pinaud, MADEP
Joanna Hall, TRC, Lowell, MA

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COMMODORE

ADVANCED SCIENCES, INC.

March 7, 2000

Mr. Jim F. Snyder
Remediation Program Manager
HQ AFCEE/MMR
322 East Inner Road
Otis ANG Base, MA 02542-5028

Subject: Final FS-12 Source Area Removal Action Summary Report, Massachusetts Military
Reservation, dated March 2000

Dear Mr. Snyder:

For the Air Force Center for Environmental Excellence (AFCEE), and as directed by Advanced Infrastructure Management Technologies, Commodore Advanced Sciences, Inc. is hereby submitting the Final FS-12 Source Area Removal Action Summary Report, dated March 2000. Responses to USEPA and MADEP comments on the draft version of the report, as agreed to by the regulators, have been incorporated into the final version of the report.

Please contact me at (865) 483-1274 if you have any questions.

Sincerely,



Joseph H. Hawk, P.E.
Oak Ridge Operations Manager

Enclosure (16 bound, 1 unbound, 1 digital)

C: Paul Marchessault, USEPA Region I (2 bound)
Leonard Pinaud, MADEP (2 bound)
Ms. Joanne Watson (1 bound)
Ms. Mary Ellen Maly (1 bound)
Mr. Larry Lumeh (1 bound)
Mr. David Hill (1 bound)
Fred Crowner, AIMTECH (1 bound, 1 unbound, 1 digital)
Project File 9406.1.D